Emissions of Persistent Organic Pollutants and other air pollutants in Iceland 1990 - 2011

Informative Inventory Report 2013

Submitted under the Convention on Long Range Transboundary Air Pollution

UMHVERFISSTOFNUN

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Preface

The Convention on Long Range Transboundary Air Pollution (CLRTAP) was adopted in 1979 and entered into force in 1983. The Convention has been extended by eight Protocols, of which Iceland has ratified the Protocol on Persistent Organic Pollutants.

According to Article 8 of the Convention, Parties shall exchange information on emissions of pollutants. To comply with this requirement, Iceland has prepared an Informative Inventory Report (IIR) for the year 2013. The IIR together with the associated Nomenclature for Reporting tables (NFR tables) is Iceland's contribution to this round of reporting under the Convention, and covers emissions in the period 1990 – 2011. This report emphasizes on emissions of Persistent Organic Pollutants, as Iceland has only ratified the Protocol on Persistent Organic Pollutants. Emissions of the indirect greenhouse gases (NO_x, CO, NMVOC) and SO_2 are provided in the NFR tables for information purposes, as they are calculated to comply with the reporting requirements of the UNFCCC. For this submission emission estimates for ammonia and particulate matter are provided for a few emission sources. A short description of the trends and the calculation method of those pollutants are given in this report.

The IIR is written by the Environment Agency of Iceland (EA).

Environment Agency of Iceland, Reykjavík, March 2013

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EXECUTIVE SUMMARY

Background

The Convention on Long-Range Transboundary Air Pollution entered into force in 1983. The Convention has been extended by eight Protocols, of which Iceland has ratified the Protocol on Persistent Organic Pollutants (POPs). The Protocol on Persistent Organic Pollutants entered into force in 2003. According to Article 8 of the Convention, Parties shall exchange information on emissions of pollutants. To comply with this requirement, Iceland has prepared an Informative Inventory Report (IIR) for the year 2013. The IIR together with the associated Nomenclature for Reporting tables (NFR tables) is Iceland's contribution to this round of reporting under the Convention, and covers emissions in the period 1990 – 2011. This report emphasizes on anthropogenic emissions of Persistent Organic Pollutants, as Iceland has only ratified the Protocol on Persistent Organic Pollutants. Anthropogenic emissions of the indirect greenhouse gases (NO_x, CO, NMVOC) and SO_2 are provided in the NFR tables for information purposes, as they are calculated to comply with the reporting requirements of the UNFCCC. For this submission emission estimates for ammonia and particulate matter are provided for a few emission sources. A short description of the trends and the calculation method of those pollutants are given in this report. Further estimates for SO_2, PM2.5 and PM10 for the volcano Eyjafjallajökull that erupted in 2010 and the volcano Grímsvötn that erupted in 2011 are provided. Emissions of heavy metals have not been estimated.

Responsible institute

The Environment Agency of Iceland (EA), an agency under the auspices of the Ministry for the Environment and Natural Resources is responsible for the annual preparation and submission of the Icelandic inventory to the Convention on Long-Range Transboundary Air Pollution. The EA participates in meetings under the UNECE Task Force on Emission Inventories and Projections and the related expert panels, where parties to the convention prepare the guidelines and methodologies on inventories.

Trends in POPs emissions

From 1990 to 2011 emissions of dioxins have decreased by 90% (Figure ES.1). The largest contributor of dioxin emissions in Iceland is commercial fishing, followed by waste incineration with and without energy recovery.

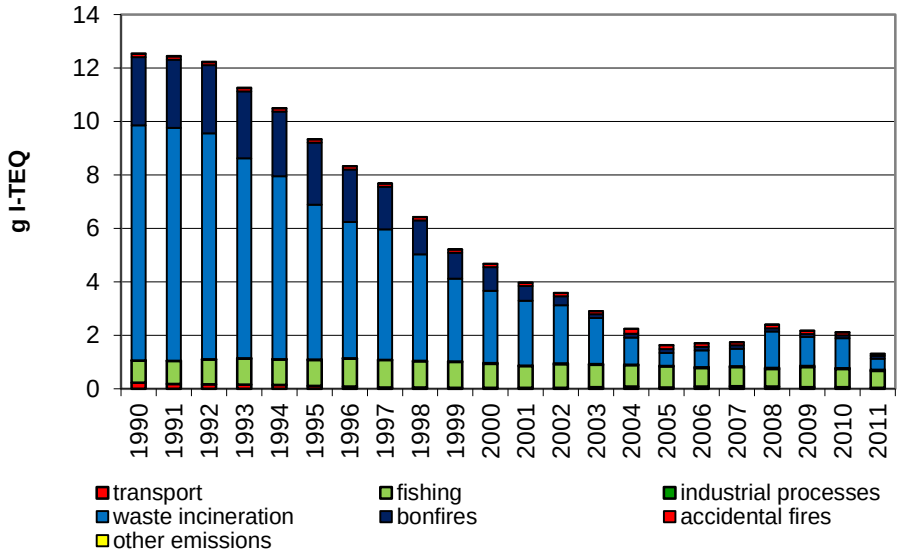

Figure ES.1 Trend in dioxins emissions from 1990 to 2011.

From 1990 to 2011 emissions of PAH4 have increased by 56% (Figure ES.2). The largest contributor of PAH4 emissions in Iceland are industrial processes, accidental fires and road transport.

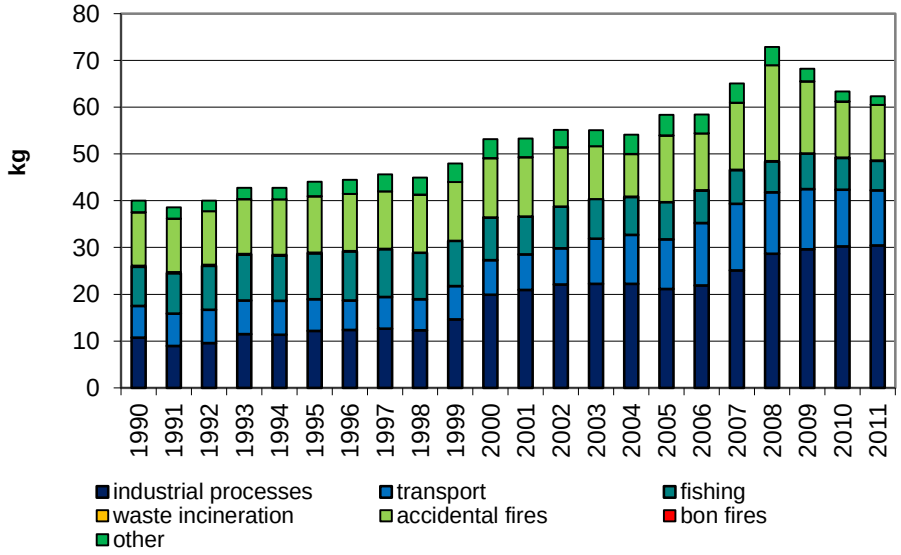

Figure ES.2 Trend in PAH4 emissions from 1990 to 2011.

From 1990 to 2011 emissions of HCB decreased by 46% (Figure ES.3). The largest contributor of HCB emissions in Iceland is waste incineration with and without energy recovery, followed by industrial processes. Emissions from waste incineration with energy recovery are reported under the Energy sector. Interpretations of the trend analysis should done with care as emissions have only been estimated for few sources.

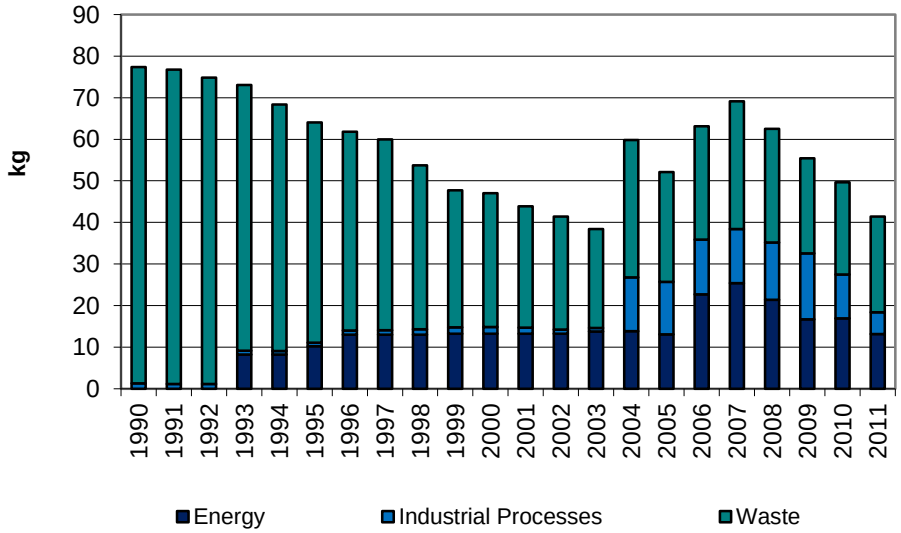

Figure ES.3 Trend in HCB emissions from 1990 to 2011

Structure of the report

The first chapter of this report provides general information on the institutional arrangements for inventory preparation, on the inventory preparation process, methodologies and data sources used. Chapter 2 gives information on emission trends and Chapters 3 to 8 give information on activity data and methodologies used for emission calculations by sector. Chapter 9 contains information on gridded data.

1 INTRODUCTION

1.1 Background information

The 1979 Convention on Long-Range Transboundary Air Pollution was signed by Iceland on 13th of November 1979 and ratified in May 1983. The Convention entered into force in August 1983. One of the requirements under the Convention is that Parties are to report their national emissions by sources.

The Convention has been extended by eight Protocols, of which the Protocol on Persistent Organic Pollutants (POP-Protocol) has been signed and ratified by Iceland. The POP-Protocol was ratified by Iceland in May 2003 and entered into force in October 2003.

The present report together with the associated NFR tables is Iceland's contribution to this round of reporting under the Convention. As Iceland has only ratified the Protocol on Persistent Organic Pollutants, the report emphasizes on anthropogenic emissions of Persistent Organic Pollutants, and covers anthropogenic emissions of dioxin/furans, PAH, HCH and HCB in the period 1990 – 2011, as well as gridded data for dioxin and PAH4 for the years 1990, 1995, 2000, 2005 and 2010. A description of the trends and calculation method is given. Anthropogenic emissions of the indirect greenhouse gases (NO_x, CO, NMVOC) and SO_2 are provided in the NFR tables for information purposes, as they are calculated to comply with the reporting requirements of the UNFCCC. For this submission emission estimates for ammonia and particulate matter are provided for a few emission sources. A short description of the trends and the calculation method of those pollutants are given in this report. Further estimates for SO_2, PM2.5 and PM10 for the volcano Eyjafjallajökull that erupted in 2010 and the volcano Grímsvötn that erupted in 2011 are provided. Emissions of heavy metals have not been estimated.

Last year several improvements were made to the inventory. The main improvements were:

- Dioxin emissions estimates from waste incineration plants (with and without energy recovery) were partly based on measurements.
- Activity data and emission factors for dioxin from bonfires were revised.
- Dioxin and PAH4 emissions from accidental fires, cremation and road paving with asphalt were included.
- Dioxin emissions from secondary aluminium production were provided.
- HCB emissions were estimated for several sources.
- Major revision was done in the sector solvent and other product use.
- NMVOC emissions from the production of food and drink were estimated.
- The transparency was greatly improved by providing more detailed description of the calculation methods.

This year the inventory has been further improved. The main improvements are:

- Dioxin and PAH emissions estimates from industrial processes (primary aluminium and ferroalloys production) are based on measurements.

- Activity data and emission factors for dioxin and PAH from accidental fires have been revised.
- Activity data for NMVOC emissions from the production of food and drink have been revised.
- Emission estimates for ammonia and nitric oxide in agriculture are provided for the first time.
- Emission estimates of particulate matter for major industrial sources (aluminium production, ferroalloys production) and agriculture have been provided for the first time.
- The transparency has been further improved by providing more detailed description of the calculation methods.

1.2 Institutional arrangement

The Environment Agency of Iceland (EA), an agency under the auspices of the Ministry for the Environment, has overall responsibility for the national inventory. EA compiles and maintains the emission inventory and reports to the Convention. Figure 1.1 illustrates the flow of information and allocation of responsibilities.

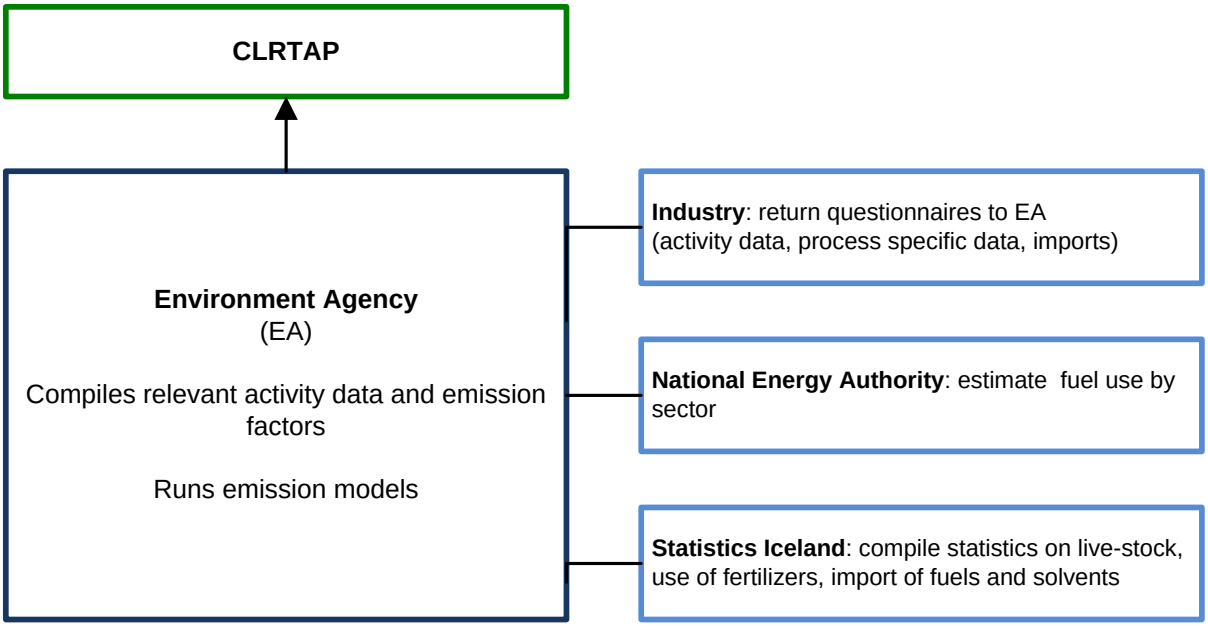

Figure 1.1 Information flow and distribution of responsibilities in the Icelandic emission inventory system for reporting to the CLRTAP

1.3 Process of inventory preparation

The EA collects the bulk of data necessary to run the general emission model, i.e. activity data and emission factors. Activity data is collected from various institutions and companies, as well as by EA directly. The National Energy Authority (NEA) collects annual information on fuel sales from the oil companies. This information was until 2008 provided on a voluntary

basis. From 2008 and onwards, Act No. 48/2007, enables the NEA to obtain sales statistics from the oil companies. Statistics Iceland provides information on population, GDP, production of various products (asphalt, food and beverages), imports of solvents and other products, the import of fertilizers and the import and export of fuels. The EA collects various additional data directly. Annually an electronic questionnaire is sent out to the industry regarding imports, use of feedstock, and production and process specific information, in accordance with Regulation no. 244/2009. Green Accounts from the industry submitted under Regulation no. 851/2002 are also used. EA also estimates activity data with regard to waste. Emission factors are mainly taken from the Emission Inventory Guidebook (EEA 2009, EEA 2007), the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP 2005), Annual Danish Inventory Report 2011 (National Environmental Research Institue 2011) as well as the Norwegian reports Utslipp til luft av dioxiner i Norge[1] (Statistic Norway 2002) and Utslipp til luft av noen miljögifter i Norge[2] (Statistics Norway 2001). Dioxin was measured at several locations in Iceland in 2011, including waste incineration plants, aluminium plants and the ferrosilicon plant. PAH was also measured at 1 aluminium plant and the ferrosilicon plant. The results from these measurements were used for waste incineration plants already in last submission. Results from the measurements at industrial sites were not available at the time of the 2012 submission, but were used in this submission.

1.4 Methodologies and data sources

The general emission model is based on the equation:

$$\text{Emission (E)} = \text{Activity level (A)} \cdot \text{Emission Factor (EF)}$$

The standard equation for estimating PAH emission factor (example for B[b]F) is:

$$\text{Emission factor (B[b]F)} = \text{Emission Factor (B[a]P)} \cdot \text{Profile ratio B[b]F/ B[a]P}$$

1.5 Key source categories

A key source category is one that is prioritized within the national inventory system because its estimate has a significant influence on the total inventory of pollutants in terms of the absolute level of emissions, the trend in emissions, or both.

A key source analysis for POPs (level assessment) is provided in Table 1.1.

[1] Utslipp til luft av dioxiner i Norge: Air emissions of dioxins in Norway
[2] Utslipp til luft av noen miljögifter i Norge: Air emissions of several pollutants in Norway

Table 1.1 Key source analysis for reported pollutants

Component	Key Categories (sorted from high to low from left to right)							Total
Dioxin	1A4c iii 48.3%	1A1a 26.7%	6C 11.0%					86.1%
PAH4	2C3 24.5%	2C2 24.3%	1A3b 18.5%					86.3%
HCB	6C 55.6%	1A1a 30.8%						86.4%

1.6 Quality assurance and quality control (QA/QC)

The objective of QA/QC activities in national emissions inventories is to improve transparency, consistency, comparability, completeness, accuracy, confidence and timeliness. A QA/QC plan for the annual inventory of Iceland has been prepared. The document describes the quality assurance and quality control programme. It includes the quality objectives and an inventory quality assurance and quality control plan. It also describes the responsibilities and the time schedule for the performance of QA/QC procedures. The QC activities include general methods such as accuracy checks on data acquisition and calculations and the use of approved standardised procedures for emission calculations, measurements, estimating uncertainties, archiving information and reporting. Source category specific QC measures have been developed for several key source categories. A quality manual for the Icelandic air emission inventory has been prepared. It is available online at:
http://ust.is/library/Skrar/Atvinnulif/Loftslagsbreytingar/Iceland_QAQC_manual.pdf. To further facilitate the QA/QC procedures all calculation sheets include a brief description of the method used. They are also provided with colour codes for major activity data entries and emissions results to allow immediate visible recognition of outliers.

1.7 Uncertainty evaluation

An estimate of the quantitative uncertainty of the Icelandic POP emission inventory has not yet been prepared.

1.8 General assessment of the completeness

In principle, the emissions inventory attempts to make estimates of all known emissions to air in as high a level of disaggregation as is possible. However, by following international guidelines on emissions reporting, there are some sources, which are deliberately not included in the national totals:

- Natural sources are not included in the national totals although estimates of some sources are made.
- Estimates of emissions from international navigation and aviation are made, and reported as memo items (excluded from national totals). For aviation this is not fully in line with the reporting guidelines for LRTAP, as cruise emissions from domestic and international aviation should be excluded from national totals, but emissions from landing and take-off from both domestic and international aviation should be

included in national total. In the Icelandic inventory all emissions from domestic aviation are included in national totals but all emissions from international aviation are excluded (in line with the reporting guidelines under the UNFCCC).

An assessment of the completeness of the emission inventory should address the issues of spatial, temporal and sectoral coverage along with all underlying source categories and activities.

In terms of spatial coverage, the emissions reported under the CLRTAP cover all activities within Iceland's jurisdiction. In this reporting round information is provided on emissions of PAH4 and dioxins within the EMEP-Grid for the years 1990, 1995, 2000, 2005 and 2010.

In the case of temporal coverage, NFR table 1 is reported for the whole time series from 1990 to 2011, for dioxins and PAH4. Emissions of HCB have been estimated for few sources for the whole timeseries, but PCB emissions are not estimated. An emission estimate of HCH that was used in Iceland from 1990 to 1992 is also provided. Further emissions of NO_x, CO, NMVOC and SO_2 are provided in the NFR table 1 for the same time period as well as emissions of NH_3 and particulate matter that have been estimated for few sources for the whole time series.

With regard to sectoral coverage some sources are not estimated. The activities/gases are not included in the present submission due to lack of data, and/or that additional work was impossible due to time constraints in the preparation of the emission inventory.

The main sources not estimated for PAH4 are:

- 1A3b v: Road transport, gasoline evaporation
- 1A3b vi: Automobile tire and break wear
- 1A3b vii: Automobile road abrasion
- 1A3d i: International maritime navigation
- 1A4a: Commercial/institutional
- 1A4b: Residential

The main sources not estimated for HCB are:

- 1A2: Manufacturing industry and construction
- 1A3: Transport
- 1A4b: Residential
- 1A4c iii: Fishing
- 2A6: Road paving with asphalt
- 2C2: Ferroalloys production
- 2F: Consumption of POPs and HM
- 3C: Solvent and other product use
- 6Cd: Cremation
- 6D: Other waste

2 TRENDS IN EMISSIONS

2.1 Emission profile in Iceland

The emissions profile for Iceland is unusual in some respects. First, emissions from generation of electricity and space heating are very low owing to the use of renewable energy sources. Almost all electricity in Iceland is produced with hydropower (73% in 2011) and geothermal power (27% in 2011). Furthermore geothermal energy sources are used for space heating (in over 90% of all homes). It should be noted, though, that significant amounts of sulphur as hydrogen sulphide are emitted from geothermal power plants. Second, over 90% of the fuel used in the energy sector is for used by mobile sources (transport, mobile machinery and fishing vessels). Thirdly, emissions from industrial processes, especially from non-ferrous metal production, have higher share in Iceland than in most other countries. This can be seen in the fact that 80% of the electricity produced in Iceland in 2011 was used in the metal production industry. The production capacity has increased considerably since 1990. In 1990, 87.839 thousand tonnes of aluminium were produced in one aluminium plant, and 62.792 thousand tonnes of ferrosilicon in one ferrosilicon plant. In 1998 a second aluminium plant was established and a third in 2007. In 1999 a third furnace was added to the ferrosilicon plant. In 2011 806.319 thousand tonnes of aluminium were produced at three aluminium plants and 105.193 thousand tonnes of ferrosilicon at the ferrosilicon plant. The emissions profile in Iceland is further influenced by the fact that Iceland was severely hit by an economic crisis late year 2008, when its three largest banks collapsed. The blow was particularly hard owing to the large size of the banking sector in relation to the overall economy as it had grown to be ten times the annual GDP. The crisis has resulted in serious contraction of the economy, a depreciation of the Icelandic króna (ISK), and a drastic increase in external debt. This has led to contraction in private consumption, rising fuel prices and collapse of the construction sector.

2.2 Trends in POPs emission

The Protocol on Persistent Organic Pollutants was adopted on 24 June 1998. It entered into force on 23 October 2003. It focuses on a list of 16 substances that have been singled out according to agreed risk criteria. The substances comprise eleven pesticides, two industrial chemicals and three by-products/contaminants. The ultimate objective is to eliminate any discharges, emissions and losses of POPs. The Protocol bans the production and use of some products outright (aldrin, chlordane, chlordecone, dieldrin, endrin, hexabromobiphenyl, mirex and toxaphene). Others are scheduled for elimination at a later stage (DDT, heptachlor, hexaclorobenzene, PCBs). Finally, the Protocol severely restricts the use of DDT, HCH (including lindane) and PCBs. The Protocol includes provisions for dealing with the wastes of products that will be banned. It also obliges Parties to reduce their emissions of dioxins, furans, PAHs and HCB below their levels in 1990 (or an alternative year between 1985 and 1995). For the incineration of municipal, hazardous and medical waste, it lays down specific limit values.

Aldrin, chlordane, chlordecone, dieldrin, endrin, hexabromobiphenyl, mirex and toxaphene have never been produced in Iceland. Of these chemicals only aldrin has been used in Iceland, though not since 1975. DDT and Heptachlor have not been used in Iceland since 1975 and were banned with a regulation in 1996. Lindan (HCH) was used until the early nineties. Sales statistics exist for 1990 to 1992, and the use of lindan was banned in 1999. PCB was banned in Iceland in 1988.

The total amount of dioxins, PAH4, HCB and HCH emitted in Iceland during the period 1990 – 2011 is presented in Table 2.1. It can be seen that emissions of PAH4 have increased by 56% from 1990 to 2011, whereas dioxin emissions have decreased by 90% and HCB emissions by 46% during the same period.

Table 2.1. Emissions of POPs in Iceland 1990 – 2011.

Year	Emissions			
	Dioxin [g I-TEQ]	PAH4 [kg]	HCB [g]	HCH [kg]
1990	12.6	40.0	77.4	1
1991	12.5	38.5	76.7	8.1
1992	12.2	40.0	74.9	0.5
1993	11.3	42.7	73.1	NO
1994	10.5	42.7	68.4	NO
1995	9.3	44.0	64.0	NO
1996	8.3	44.4	61.8	NO
1997	7.7	45.6	60.0	NO
1998	6.4	44.9	53.7	NO
1999	5.2	47.9	47.7	NO
2000	4.7	53.1	47.0	NO
2001	4.0	53.3	43.9	NO
2002	3.6	55.1	41.4	NO
2003	2.9	55.1	38.4	NO
2004	2.3	54.1	59.8	NO
2005	1.6	58.4	52.1	NO
2006	1.7	58.4	63.1	NO
2007	1.7	65.8	69.1	NO
2008	2.4	72.1	62.5	NO
2009	2.2	68.2	55.4	NO
2010	2.1	63.4	49.6	NO
2011	1.3	62.3	41.4	NO
Trend 1990 – 2011	-90%	56%	-46%	-

2.2.1 Trends in dioxin emissions

Dioxins form a family of toxic chlorinated organic compounds that share certain chemical structures and biological characteristics. Dioxins are members of two closely related families: the polychlorinated dibenzo(p)dioxins (PCDDs; 75 congeners) and polychlorinated dibenzofurans (PCDFs; 135 congeners). Dioxins bio-accumulate in humans and wildlife due to their fat solubility and 17 of these compounds are especially toxic. Dioxins are formed as

a result of combustion processes such as commercial or municipal waste incineration and from burning fuels like wood, coal or oil. Dioxins can also be formed in natural processes such as forest fires. Dioxins also enter the environment through the production and use of organochlorine compounds, chlorine bleaching of pulp and paper, certain types of chemical manufacturing and processing, and other industrial processes that are able to create small quantities of dioxins. Cigarette smoke also contains small amounts of dioxins.

Emissions of dioxins are given in g I-TEQ. 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) is the most toxic of the dioxin congeners. Other congeners (or mixtures thereof) are given a toxicity rating from 0 to 1, where TCDD is 1. The total dioxin toxic equivalence (TEQ) value expresses the toxicity as if the mixture were pure TCDD.

In 1990, the total emissions of dioxins in Iceland were 12.6 g I-TEQ. In 2011 total emissions were 1.3 g I-TEQ. This implies a decrease of 90% over the time period. Table 2.2 shows the emissions by source from 1990 to 2011.

Table 2.2. Emissions of dioxin by sector 1990 – 2011, g I-TEQ.

Year	Transport	Fishing	Indurstrial processes	Waste incineration (with and without ER)	Bonfires	Accidental fires	Other emissions	TOTAL
1990	0.2	0.8	0.02	8.8	2.6	0.1	0.02	12.6
1991	0.2	0.9	0.01	8.7	2.6	0.1	0.02	12.5
1992	0.2	0.9	0.01	8.4	2.6	0.1	0.02	12.2
1993	0.2	1.0	0.02	7.5	2.5	0.1	0.03	11.3
1994	0.1	1.0	0.01	6.8	2.4	0.1	0.01	10.5
1995	0.1	1.0	0.02	5.8	2.3	0.1	0.01	9.3
1996	0.1	1.0	0.02	5.1	2.0	0.1	0.01	8.3
1997	0.0	1.0	0.02	4.9	1.6	0.1	0.01	7.7
1998	0.0	1.0	0.02	4.0	1.3	0.1	0.01	6.4
1999	0.0	1.0	0.02	3.1	1.0	0.1	0.01	5.2
2000	0.0	0.9	0.03	2.7	0.9	0.1	0.01	4.7
2001	0.0	0.8	0.03	2.4	0.5	0.1	0.01	4.0
2002	0.0	0.9	0.03	2.2	0.3	0.1	0.01	3.6
2003	0.1	0.8	0.03	1.7	0.2	0.1	0.01	2.9
2004	0.1	0.8	0.03	1.0	0.1	0.2	0.01	2.3
2005	0.0	0.8	0.03	0.5	0.1	0.1	0.01	1.6
2006	0.1	0.7	0.03	0.6	0.1	0.1	0.01	1.7
2007	0.1	0.7	0.04	0.7	0.1	0.1	0.01	1.7
2008	0.1	0.7	0.04	1.4	0.1	0.1	0.01	2.4
2009	0.1	0.8	0.04	1.1	0.1	0.1	0.01	2.2
2010	0.1	0.7	0.04	1.1	0.1	0.1	0.01	2.1
2011	0.0	0.6	0.04	0.4	0.1	0.1	0.01	1.3
Trend 1990 - 2011	-83%	-24%	159%	-95%	-96%	-31%	-77%	-90%

Figure 2.1 shows the main sources of emissions in 2011 and Figure 2.2 shows the percentage change in emissions by source categories from 1990 to 2011, compared to the 1990 level.

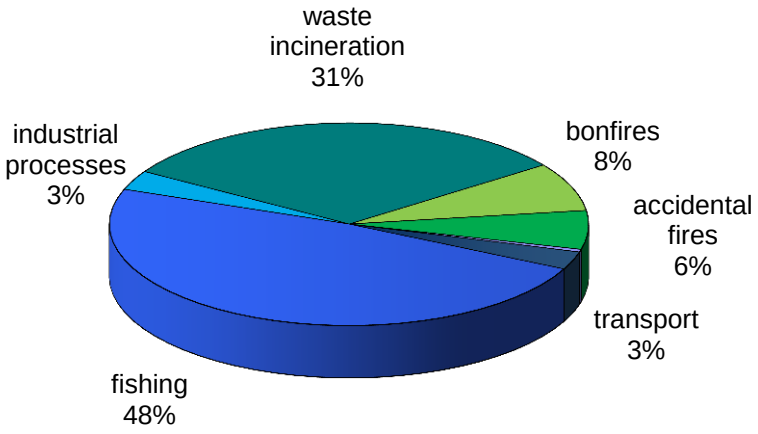

Figure 2.1. Emissions of dioxin by sector in 2011.

The main sources of dioxin emissions in 2011 are commercial fishing (48%) and waste incineration with and without energy recovery (31%; 26.7% and 3.3% respectively). Other important sources are bonfires (8%) and accidental fires (6%).

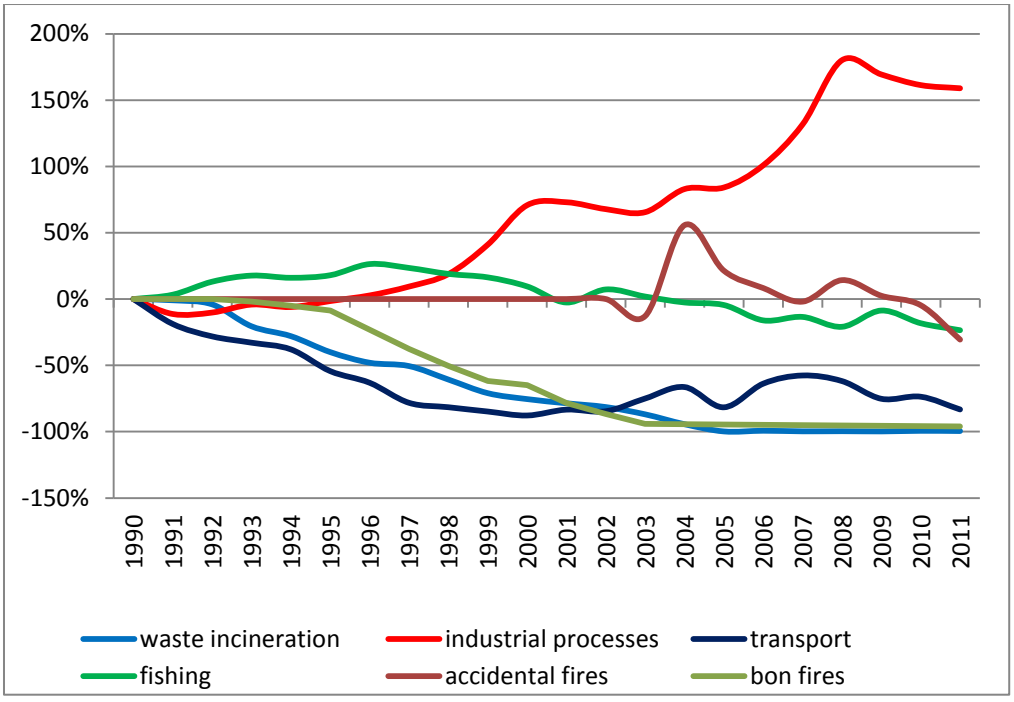

Figure 2.2. Percentage changes in emissions of dioxin by sector from 1990 to 2010, compared to 1990.

Practices of waste disposal treatment have undergone a radical change in Iceland since 1990. This is the main reason for the decline in emissions by 99.5% from 1990 to 2011.

Open pit burning that used to be the most common means of waste disposal outside the capital area, has gradually decreased since 1990. At the same time total amount of waste being incinerated has decreased while increasing levels have been incinerated with energy recovery (reported under 1A1a and 1A4). Open pit burning is practically non-existent today, the last site was closed by the end of 2010. Emissions from bonfires around New Year celebrations are included in the Waste Incineration sector. Emissions from bonfires have decreased since 1990, due to the fact that bonfires are fewer and better organized. Guidelines for bonfires, published in 2000, include restrictions on size, burnout time and the material allowed.

Emissions from electricity generation and space heating are very low because they are generated from renewable energy sources. Emissions in this sector are dominated by emissions from waste incineration with energy recovery, which are reported under 1A1a and 1A4.

From 1990 to 2011 emissions from road transport decreased by 91% despite the 143% growth in the number of vehicles and 50% increase in fuel consumption. This is due to the phase-out of leaded fuel.

Emissions have decreased since 1990 from the fishing sector as well as from the sector other transport due to less fuel consumption in these sectors. For commercial fishing this decline amounted to 24%. Emissions from commercial fishing are high compared to the fuel consumption. The emission factors for burning fuel at sea are much higher than when burning fuel on land, due to the presence of salt (and therefore chlorine) in the air going to the engines. In 1990, emissions from commercial fishing were 7% of the national total. In 2011, emissions from commercial fishing amounted to 48% as emissions from most other sources have decreased more during since 1990.

Emissions from industrial processes have increased by 159% during the period due to increased activity in the non-ferrous metals production sector. Aluminium production has increased from 87.839 thousand tonnes in 1990 to 806.319 thousand tonnes in 2011, with the main increase after 2005. Production of ferrosilicon has increased from 62.792 thousand tonnes to 105.193 thousand tonnes in the same period.

Emissions from accidental fires have decreased by 31% from 1990 to 2011. A peak in emissions from accidental fires can be seen in 2004 when a major fire broke out at a recycling company (Hringrás). In the fire 300 tonnes of tires, among other separated waste materials, burned.

2.2.2 **Trends in PAH emissions**

The polycyclic aromatic hydrocarbons (PAH) are molecules built up of benzene rings which resemble fragments of single layers of graphite. PAHs are a group of approximately 100 compounds. Most PAHs in the environment arise from incomplete burning of carbon-

containing materials like oil, coal, wood or waste. Fires are able to produce fine PAH particles, they bind to ash particles and sometimes move long distances through the air. Thus PAHs have been ubiquitously distributed in the natural environment for thousands of years. The four compounds benzo(a)pyren, benzo(b)fluoranthen, benzo(k)fluoranthen and indeno(1,2,3-cd)pyren are used as PAH indicators for the purposes of emission inventories, as specified in the POP- Protocol.

In 1990, the total emissions of PAH4 in Iceland were 40.0 kg. In 2011 total emissions were 62.3 kg. This implies an increase of 56% over the time period. Table 2.3 shows the emissions by source from 1990 to 2011.

Table 2.3. Emissions of PAH4 by sector 1990 – 2011, kg.

Year	Transport	Fishing	Indurstrial processes	Waste incineration (with and without ER)	Bonfires	Accidental fires	Other emissions	TOTAL
1990	6.8	8.3	10.7	0.3	0.04	11.4	2.4	40.0
1991	7.0	8.6	8.9	0.3	0.04	11.4	2.3	38.5
1992	7.1	9.4	9.5	0.3	0.04	11.4	2.2	40.0
1993	7.2	9.8	11.5	0.2	0.04	11.6	2.4	42.7
1994	7.2	9.6	11.4	0.2	0.04	11.8	2.4	42.7
1995	6.8	9.8	12.2	0.2	0.04	12.0	3.1	44.0
1996	6.3	10.5	12.4	0.2	0.04	12.1	3.0	44.4
1997	6.8	10.2	12.6	0.2	0.04	12.2	3.6	45.6
1998	6.7	9.9	12.3	0.2	0.03	12.3	3.6	44.9
1999	7.1	9.7	14.6	0.1	0.03	12.5	3.9	47.9
2000	7.4	9.1	19.9	0.1	0.04	12.6	4.0	53.1
2001	7.6	8.1	20.9	0.1	0.03	12.6	3.9	53.3
2002	7.7	8.9	22.1	0.1	0.03	12.6	3.7	55.1
2003	9.7	8.5	22.2	0.0	0.03	11.3	3.4	55.1
2004	10.5	8.1	22.2	0.1	0.03	9.1	4.1	54.1
2005	10.6	7.9	21.1	0.1	0.02	14.2	4.4	58.4
2006	13.4	7.0	21.9	0.1	0.02	12.1	4.0	58.4
2007	14.3	7.2	25.1	0.1	0.02	14.3	4.1	65.8
2008	13.1	6.6	28.7	0.1	0.02	20.5	3.8	72.1
2009	12.9	7.6	29.6	0.1	0.02	15.3	2.7	68.2
2010	12.1	6.8	30.2	0.1	0.02	11.9	2.2	63.4
2011	11.8	6.3	30.4	0.1	0.02	11.8	1.8	62.3
Trend 1990 - 2011	73%	-24%	184%	-67%	-60%	4%	-25%	56%

Figure 2.3 shows the main sources of emissions in 2011 and Figure 2.4 shows the percentage change in emissions by source categories from 1990 to 2011, compared to the 1990 level.

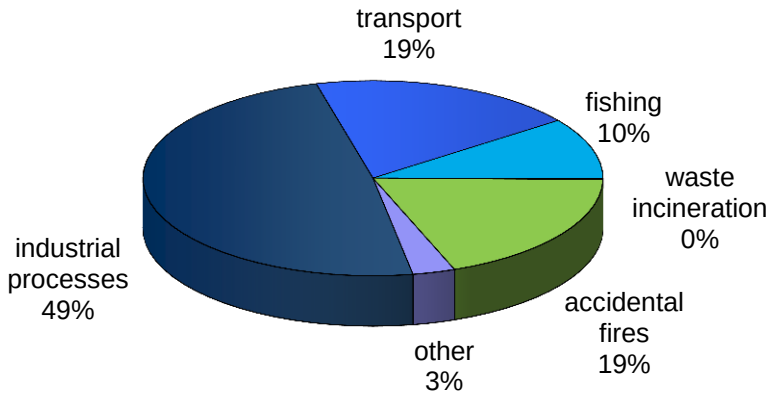

Figure 2.3. Emissions of PAH4 by sector in 2011.

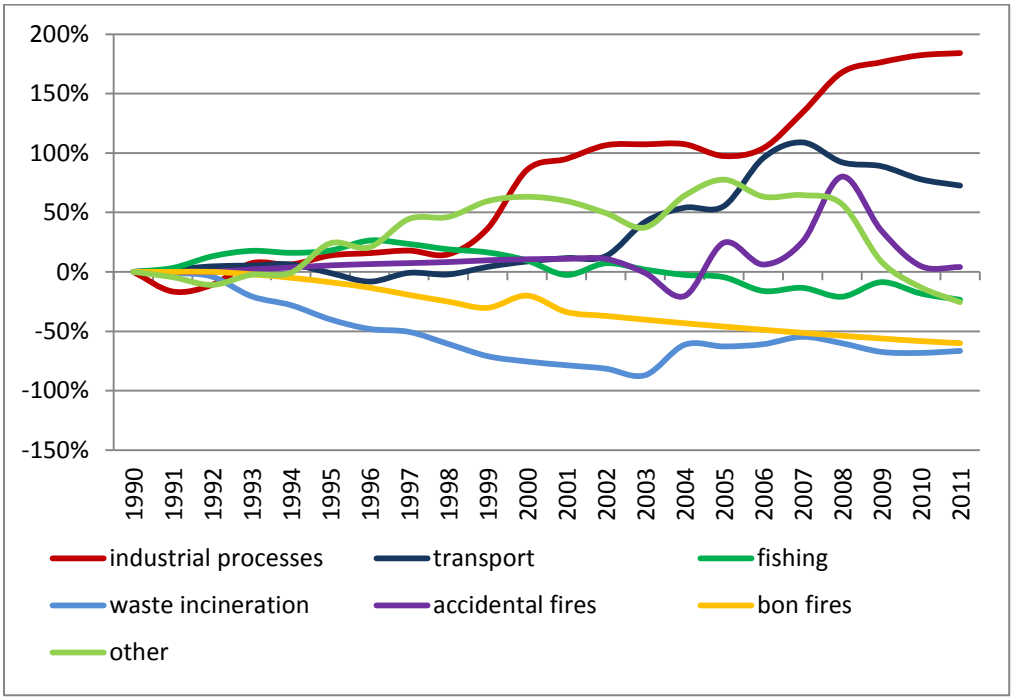

Figure 2.4. Percentage changes in emissions of PAH4 by sector from 1990 to 2011, compared to 1990.

The main reasons for the growth in emissions from 1990 to 2011 are increased emissions from industrial processes, due to increased production capacity in the non-ferrous metals production sector.

As stated above, the production capacity in the metal production sector has increased substantially. Aluminium production has increased from 87.839 thousand tonnes in 1990 to 806.319 thousand tonnes in 2011 and from ferrosilicon production has increased from 62.792 thousand tonnes in 1990 to 105.193 thousand tonnes in 2011. The main increase in emissions is seen between 1998 and 2000 on the one hand due to increased production capacity both in the aluminium and the ferrosilicon industry, and from 2006 to 2008 on the other due to the increased production capacity in the aluminium industry.

By the mid 1990's economic growth gained momentum in Iceland. Iceland experienced until 2007 one of the highest growth rates of GDP among OECD countries. Late year 2008, Iceland was severely hit by an economic crisis when its three largest banks collapsed. The crisis resulted in serious contraction of the economy, followed by increased unemployment and a depreciation of the Icelandic króna. The increase in GDP from 1990 to 2007 resulted in higher emissions from most sources, in particular from road transport and the construction sector. The crisis led to collapse of the construction sector in the autumn 2008. Emissions from the construction sector were 55% lower in 2011 than in 2007 and emissions from the cement plant were 69% lower.

Road transport is an important source of PAH4 emissions in Iceland. Since 1990 the vehicle fleet in Iceland has increased by 143%. Furthermore the trend until 2007 was towards larger passenger cars which consume more fuel. In recent years the share of diesel cars has also increased substantially. This led to increased emissions from road transportation. Emissions from road transport in 2007 were 122% higher than in 1990. In 2008 fuel prices rose significantly leading to lower emissions from the sector compared to the year before. PAH4 emissions from road transport in 2011 were 14% below the 2007 level, but 90% above the 1990 emissions.

Accidental fires are important source of PAH4 emissions in Iceland. Emissions from accidental fires have increased by 4% from 1990 to 2011. A peak in emissions from accidental fires can be seen in 2008 when a unusually many vehicle fires were registered. Many of these fires are believed not to be "accidental" but rather man-made ignition. Many of the vehicles that caught (or were set on) fire this year had been financed with loans, that were in arrears. The depreciation of the Icelandic króna in 2008 resulted in the huge inflation of car loans, as they were mostly in foreign currency.

Emissions from commercial fishing rose from 1990 to 1996 because a substantial portion of the fishing fleet was operating in distant fishing grounds, consuming more fuel. From 1996 the emissions decreased again reaching 1990 levels in 2004. In 2011, the emissions were 24% below 1990 levels. Annual changes in emissions reflect the inherent nature of the fishing industry.

Emissions from the waste incineration have decreased by 67% from 1990 to 2011, partly because primitive incineration plants and open pit burning were closed down.

2.2.3 Trends in HCB emissions

Hexachlorobenzene (HCB) or perchlorobenzene is a chlorocarbon with the molecular formula C_6Cl_6. HCB is a fungicide that was first introduced in 1945 for seed treatment, especially for control of bunt of wheat. HCB is currently emitted as a by-product in the manufacture of several chlorinated solvents. On the whole, processes resulting in dioxin formation also result in HCB emissions. HCB is considered to be probable human cancerogen. HCB is a very persistent environmental chemical due to its chemical stability and resistance to biodegradation. Analysis of trends in HCB emissions in Iceland must be interpreted with care as only few sources have been estimated. In 1990, the total emissions of HCB in Iceland were 77.4 g. In 2011 total emissions were 41.4 g. This implies a decrease of 46% over the time period.

Table 2.4 shows the emissions by source from 1990 to 2011. Figure 2.5 shows the main sources of emissions in 2011.

Table 2.4. Emissions of HCB by sector 1990 – 2011, g.

Year	Energy industries and commercial	Industrial processes	Waste	TOTAL
1990	-	1.3	76.1	77.4
1991	-	1.2	75.6	76.7
1992	-	1.1	73.8	74.9
1993	8.2	1.0	63.9	73.1
1994	8.2	0.9	59.3	68.4
1995	10.2	0.9	52.9	64.0
1996	13.0	1.0	47.8	61.8
1997	13.0	1.1	45.9	60.0
1998	13.3	1.3	39.4	53.7
1999	13.3	1.5	33.0	47.7
2000	13.3	1.6	32.2	47.0
2001	13.3	1.4	29.2	43.9
2002	13.3	0.9	27.2	41.4
2003	13.8	0.8	23.7	38.4
2004	13.9	12.9	33.0	59.8
2005	13.1	12.6	26.4	52.1
2006	16.7	13.2	33.3	63.1
2007	17.8	13.0	38.3	69.1
2008	13.4	13.7	35.4	62.5
2009	9.9	15.9	29.6	55.4
2010	10.3	10.6	28.8	49.6
2011	13.1	5.3	23.0	41.4
Trend 1990 – 2011	-	321%	-70%	-46%

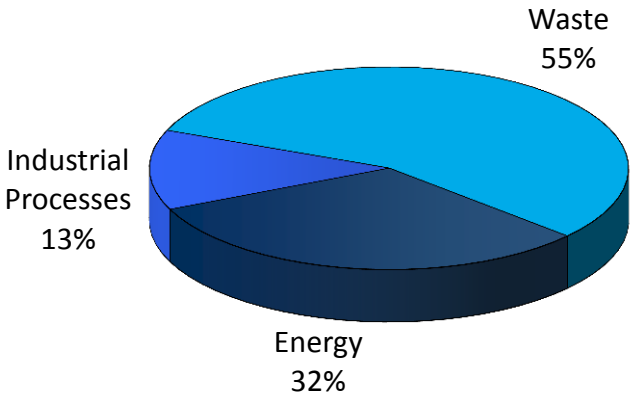

Figure 2.5. Emissions of HCB by sector in 2011.

The main sources of HCB emissions are waste incineration with and without energy recovery and industrial processes (secondary aluminium production and cement production). A sudden increase in HCB emissions from industrial processes is seen in 2004 when a secondary aluminium production plant was established. The production at the plant went down by 50% from 2010 to 2011.

2.3 Emission trends for NO_x, NMVOC, CO, SO_2, NH_3 and particulates

Nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOC), carbon monoxide (CO), ammonia (NH_3) and particulate matter (TSP, PM10, PM2.5) have an adverse effect on human health and the environment. Iceland has only ratified the POP protocol of the CLRTAP. Reporting of other pollutants than POPs is therefore not obligatory. Emissions of NO_x, CO, NMVOC and SO_2 are provided in the NFR tables for information purposes, as they are calculated to comply with the reporting requirements of the UNFCCC. For this submission emission estimates for ammonia and particulate matter are provided for a few emission sources. A short description of the trends of those pollutants is given in the following section.

2.3.1 Nitrogen oxides (NOx)

The main sources of nitrogen oxides in Iceland are commercial fishing, transport, and the manufacturing industry and construction (see Figure 2.6). The NO_x emissions from commercial fishing rose from 1990 to 1996 when a substantial portion of the fishing fleet was operating in distant fishing grounds. From 1996 emissions decreased, reaching the 1990 levels in 2001. Emissions rose again in 2002 but have declined since with exception of 2009 due to less fuel consumption. Emissions in 2011 were 24% below the 1990 level. Annual changes are inherent to the nature of fisheries. Emissions from transport are dominated by road transport. These emissions have decreased rapidly (by 27%) after the use of catalytic converters in all new vehicles became obligatory in 1995, despite the fact that fuel

consumption has increased by 40%. The rise in emissions from the manufacturing industries and construction until 2007 are dominated by increased activity in the construction sector during the period. In 2011 emissions from manufacturing industry and construction were 37% lower than in 1990. This is due to the collapse of the construction sector (including less emission from the cement plant) and to less fuel consumption at fishmeal plants as fuel has been replaced with electricity and production has decreased. Total NO_x emissions, like the emissions from fishing, increased until 1996 and decreased thereafter until 2001. Emission rose again between 2001 and 2004 and then decreased again. Total NO_x emissions in 2010 were 23% below the 1990 level.

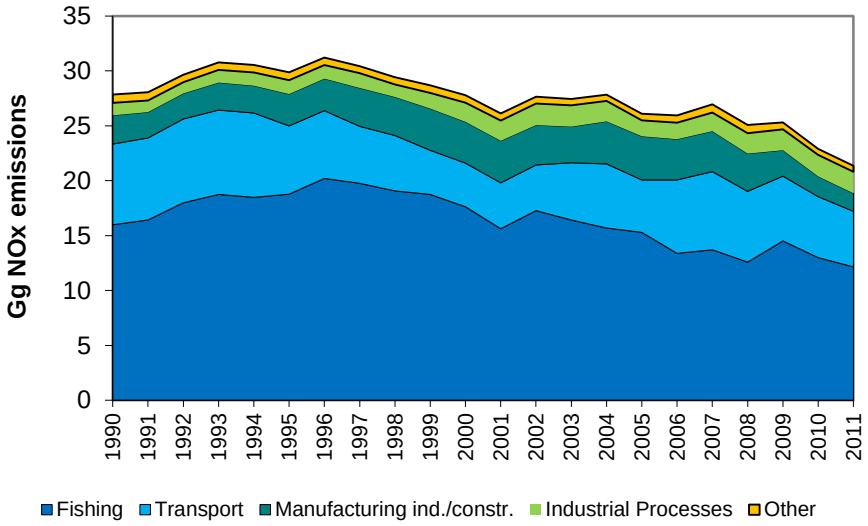

Figure 2.6. Emissions of NOx by sector 1990 – 2011, Gg.

2.3.2 Non-methane volatile organic compounds (NMVOC)

The main sources of non-methane volatile organic compounds are transport and solvent use, as can be seen in Figure 2.7. Emissions from transport are dominated by road transport. These emissions decreased rapidly after the use of catalytic converters in all new vehicles became obligatory in 1995. Emissions from solvent use have been around 1 Gg and show a downward trend in recent years. Other emissions include emissions from industrial processes, where food and drink production is the most prominent contributor. The total emissions showed a downward trend from 1994 to 2011. The emissions in 2011 were 56% below the 1990 level.

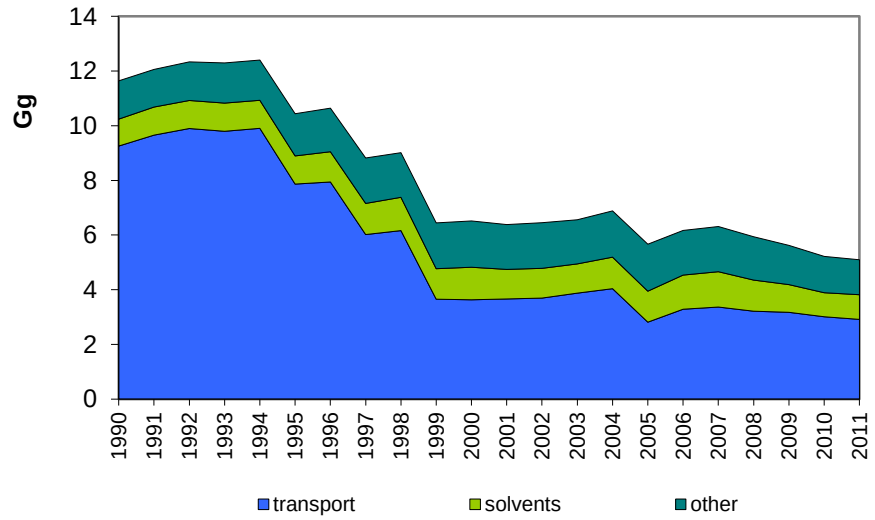

Figure 2.7. Emissions of NMVOC by sector 1990 – 2011, Gg.

2.3.3 Carbon monoxide (CO)

Transport is the most prominent contributor to CO emissions in Iceland, as can be seen in Figure 2.8. Emissions from transport are dominated by road transport. These emissions have decreased rapidly after the use of catalytic converters in all new vehicles became obligatory in 1995. Total CO emissions show, like the emissions from transport, a rapid decrease after 1990. The emissions in 2011 were 60% below the 1990 level.

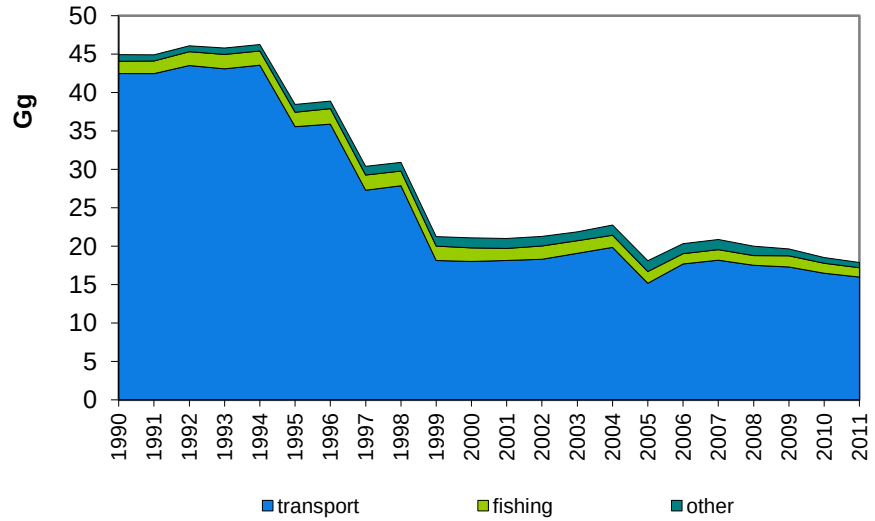

Figure 2.8. Emissions of CO by sector 1990 – 2011, Gg.

2.3.4 Sulphur dioxide (SO_2)

Geothermal energy exploitation is by far the largest source of sulphur emissions in Iceland. Sulphur is emitted from geothermal power plants in the form of H_2S. Emissions have increased by 384% since 1990 due to increased activity in this field, as electricity production at geothermal power plants has increased 15-fold since 1990. The expansion of the metal

production sector has been accommodated with parallel investments in increased power capacity, especially after 2005. Other significant sources of sulphur dioxide in Iceland are industrial processes and manufacturing industry and construction (see Figure 2.9). Emissions from industrial processes are dominated by metal production. Until 1996 industrial process sulphur dioxide emissions were relatively stable. Since then, the metal industry has expanded. In 1990, 88,839 tonnes of aluminium were produced at one plant and 62,792 tonnes of ferroalloys at one plant. In 2011 806,319 tonnes of aluminium were produced at three plants and 105,193 tonnes of ferroalloys were produced at one plant. This led to increased emissions of sulphur dioxide (306% increase of emissions from ferroalloys and aluminium production compared to 1990 levels). The fishmeal industry is the main contributor to sulphur dioxide emissions from fuel combustion in the sector Manufacturing Industries and Construction. Emissions from the fishmeal industry increased from 1990 to 1997 but have declined since as fuel has been replaced with electricity and production has decreased; the emissions were 68% below the 1990 level in 2010.

Sulphur emissions from the commercial fishing fleet depend upon the use of residual fuel oil. When fuel prices go up, the use of residual fuel oil rises and the use of gas oil drops. This leads to higher sulphur emissions as the sulphur content of residual fuel oil is significantly higher than in gas oil. The rising fuel prices since 2008 have led to higher sulphur emissions from the fishing fleet in recent years. Emissions from the fishing fleet in 2011 were about the same as 1990 although fuel consumption was 24% less.

In 2011 total sulphur emissions in Iceland, calculated as SO_2, were 283% above the 1990 level, but 112% above the 1990 level when excluding emissions from geothermal power plants (Fig. 2.9).

In 2010 the volcano Eyjafjallajökull started erupting. The eruption lasted from 14th of April until 23rd of May. During that time 127 Gg of SO_2 were emitted or 71% more than total man made emissions in 2010. In 2011 the volcano Grímsvötn started erupting. The eruption lasted from 21st until 28th of May. During that time 1000 Gg of SO_2 were emitted or 12 times more than total man made emissions in 2011. These emissions are not included in national totals.

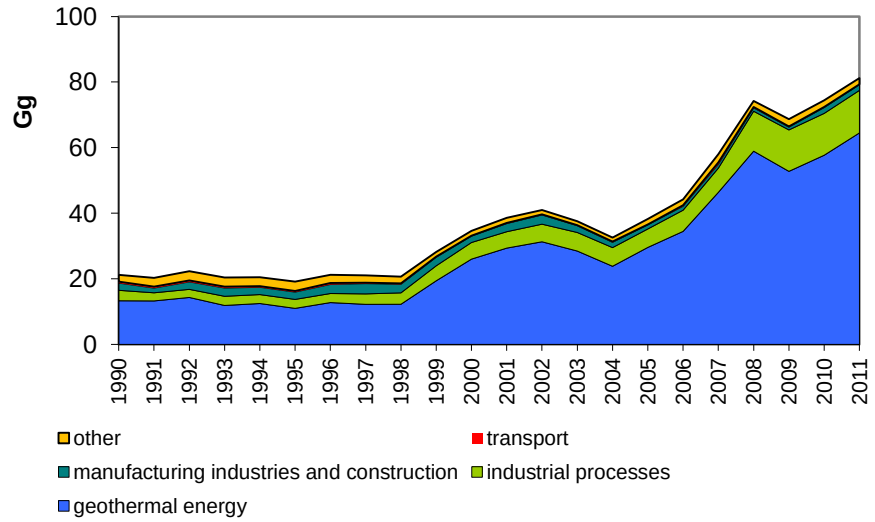

Figure 2.9. Emissions of SO_2 by sector 1990 – 2011, Gg.

2.3.5 **Ammonia (NH_3)**

Ammonia emissions have only been estimated for the agriculture sector. Manure management, manure deposition of grazing animals on pastures, and fertilizer application are the main sources. Emissions have been fluctuating between 5 and 5.5 Gg NH_3 since 1990. Emissions decreased by 11% between 1990 and 2004 but have been increasing again since then. Therefore the overall trend between 1990 and 2011 is a 4% decrease. The main driver behind the general trend and its oscillations is the trend in livestock population. Sheep and cattle are the main ammonia emissions causing categories constituting more than 80% of total NH_3 emissions. NH_3 emissions from fertilizer application plays only a minor role as can be seen in Figure 2.10.

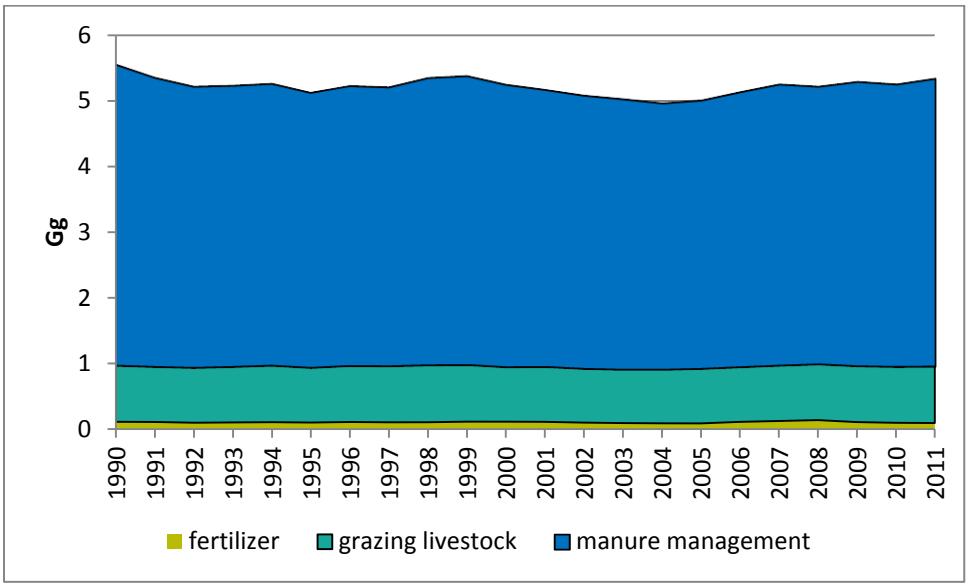

Figure 2.10. Emissions of NH_3 from 1990 – 2011, Gg.

2.3.6 **Particulate matter (PM10)**

Emissions of particulate matter (TSP, PM10, PM2.5) have only been estimated for aluminium production, ferroalloys production, the agriculture sector and from tobacco smoking. The trend in emissions of PM10 can be seen in Figure 2.9. As emissions have only been estimated for few sources the trend should be interpreted with care.

Emissions from the metal production sector overweigh the estimated emissions of particulates in Iceland. As stated above, the production capacity in the metal production sector has increased substantially. Aluminium production has increased from 87.839 thousand tonnes in 1990 to 806.319 thousand tonnes in 2011 and from ferrosilicon production has increased from 62.792 thousand tonnes in 1990 to 105.193 thousand tonnes in 2011.

Agricultural emissions stem from practices associated with the cultivation of grass and barley fields as well as livestock manure management. Total PM emissions from agriculture were 0.15 Gg in 2011.

In 2010 the volcano Eyjafjallajökull started erupting. The eruption lasted from 14th of April until 23rd of May. During that time around 6000 Gg of PM10 were emitted or around 10,000 times more than total estimated man made emissions in 2010. In 2011 the volcano Grímsvötn started erupting. The eruption lasted from 21st until 28th of May. The eruption at Grímsvötn was much larger than at Eyjafjallajökull, and it has been estimated that during the first day more sulphur and particulates were emitted than during all the Eyjafjallajökull eruption. An estimate of the total particulates emitted has not been estimated but the EA has scaled the emissions of particulates using the ratio of sulphur emissions from the two

eruptions (1000/127). This gives an approximate estimate of of around 47,000 Gg PM10 and 13,000 Gg of PM2.5. These emissions are not included in national totals.

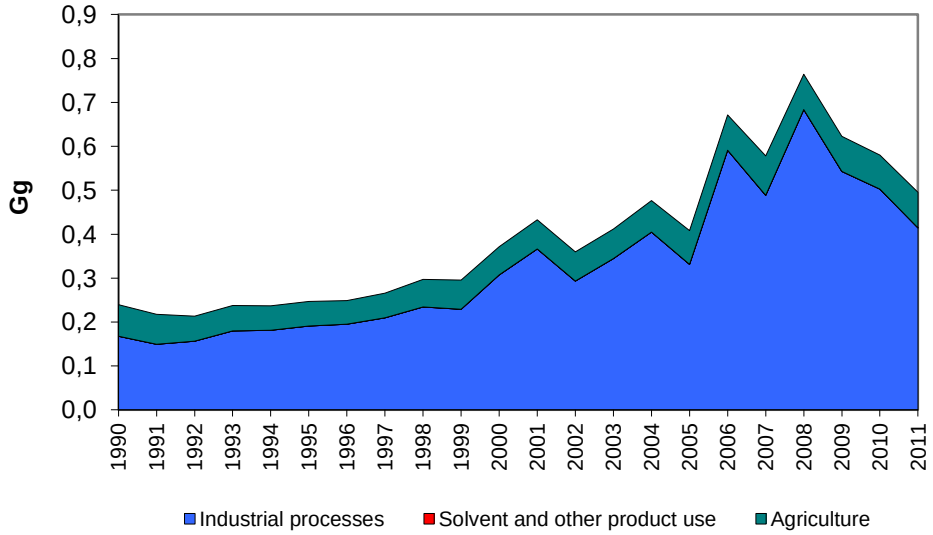

Figure 2.11. Emissions of PM10 from 1990 – 2011, Gg.

3 ENERGY

3.1 Introduction

The Energy sector in Iceland is unique in many ways. Iceland ranks 1st among OECD countries in the per capita consumption of primary energy. The per capita primary energy consumption in 2011 was about 737 GJ. However, the proportion of domestic renewable energy in the total energy budget is about 85%, which is a much higher share than in most other countries. The cool climate and sparse population calls for high energy use for space heating and transport. Also, key export industries such as fisheries and metal production are energy-intensive. The metal production industry used around 80% of the total electricity produced in Iceland in 2011. Iceland relies heavily on its geothermal energy sources for space heating (over 90% of all homes) and electricity production (27% of the electricity) and on hydropower for electricity production (73% of the electricity). Thus, emissions in this sector originate predominantly from mobile sources: road transport, fishing and equipment in the construction sector, as well as waste incineration with energy recovery.

Methodology

Emissions from fuel combustion are estimated at the sectoral level. They are calculated by multiplying energy use by source and sector with pollutant specific emission factors. Activity data is provided by the National Energy Authority (NEA), which collects data from the oil companies on fuel sales by sector. The division of fuel sales by sector does not reflect the IPCC/NFR sectors perfectly so EA has made adjustments to the data where needed to better reflect the IPCC/NFR categories. Further explanation of this adjustment is given in Annex I. This applies for the sectors 1A1a Energy industries, 1A2 Manufacturing industry (stationary combustion) and 1A4 Residential. Emissions from waste incineration with energy recovery are reported under 'energy industries' and 'commercial' but a description of the method is under the waste section. Fuel combustion activities are divided into two main categories; stationary and mobile combustion. Stationary combustion includes Energy Industries, Manufacturing Industries and a part of the Other sectors (Residential and Commercial/Institutional sector). Mobile combustion includes Civil Aviation, Road Transport, Navigation, Fishing (part of the Other sectors), Mobile Combustion in Construction (part of Manufacturing Industries and Construction sector) and International Bunkers.

The QC activities include general methods such as accuracy checks on data acquisition and calculations and the use of approved standardised procedures for emission calculations, estimating uncertainties, archiving information and reporting, as further elaborated in the QA/QC manual. No source specific QA/QC procedures have been developed yet for the Energy sector.

3.2 Energy Industries (1A1)

Energy Industries include emissions from electricity and heat production. Iceland has extensively utilised renewable energy sources for electricity and heat production, thus emissions from this sector are low. For dioxin, PAH4, SO_2 and NMVOC waste incineration with energy recovery is the main source of emissions for this category. Activity data on fuel use for the energy industries are based on data provided by the NEA and adjusted by EA, see Annex I. Activity data on waste is collected by EA directly from the plants.

Electricity

Electricity was produced from hydropower, geothermal energy and fuel combustion in 2011 (Table 3.1.), with hydropower as the main source of electricity (NEA, 2013). Electricity was produced with fuel combustion at a two locations that are located far from the distribution system (two sparsely populated islands, Grimsey and Flatey). Some public electricity facilities have emergency backup fuel combustion power plants which they can use when problems occur in the distribution system. Those plants are, however, very seldom used, apart from testing and during maintenance.

Table 3.1. Electricity production in Iceland (GWh).

	1990	1995	2000	2005	2008	2009	2010	2011
Hydropower	4,159	4,678	6,352	7,014	12,427	12,279	12,592	12,507
Geothermal	283	288	1,323	1,658	4,037	4,553	4,465	4,701
Fuel combustion	5.6	8.4	4.4	7.8	2.7	2.9	1.7	2,1
Total	**4,447**	**4,977**	**7,679**	**8,680**	**16,467**	**16,835**	**17,059**	**17,210**

Activity data (the amount of gasoil used) for electricity production with fuel combustion is calculated from the information on electricity production (GWh), based on the energy content of the gasoil (43.33 TJ/kt) assuming 34% efficiency.

Heat

Geothermal energy was the main source of heat production in 2011. Some district heating facilities, that lack access to geothermal energy sources, use electric boilers to produce heat from electricity. They depend on curtailable energy. These heat plants have back up fuel combustion in case of electricity shortages or problems in the distribution system. Three district heating facilities burn waste to produce heat and are connected to the local distribution system. Emissions from these waste incineration plants are reported under Energy Industries. A description of the method to estimate emissions from waste incineration plants is given in Chapter 7.

Activity data for electricity and heat production with fuel combustion and waste incineration are given in Table 3.2. No fuel consumption for heat production was reported by the NEA for 2010 and 2011. The use of residual fuel oil in 2007 was much higher than in surrounding years. In 2007 a new aluminium plant was established in Iceland. Because the Kárahnjúkar hydropower project (hydropower plant built for this aluminium plant) was delayed, the

aluminium plant was supplied for a while with electricity from the distribution system. This led to electricity shortages for the district heating system and industry depending on curtailable energy leading to increased fuel combustion. The different fuel composition from year to year (waste, fuel) effect the IEF. For example the IEF for dioxin in this sector is higher in years when fuel combustion is low and the sector is dominated by waste incineration. Unusual years have been 1995 (issues in the electricity distribution system caused by snow avalanches in northwest Iceland (the Westfjords) and icing in the northern part of the country), 1997/1998 (unfavourable weather conditions for hydropower plants during the winter) and 2007 (explained above).

Table 3.2. Fuel combustion and waste incineration (kt) for electricity and heat production.

	1990	1995	2000	2005	2008	2009	2010	2011
Gas/Diesel oil (electricity)	1.4	2.1	1.1	1.9	0.7	0.7	0.4	0.5
Residual fuel oil (heat)	3.0	3.1	0.1	0.2	0.1	0.1	-	-
Solid waste (heat)	NO	4.7	6.0	6.0	10.3	8.0	8.1	6.4

Emission factors for dioxin are taken from the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP 2005). They are 0.5 µg I-TEQ/TJ (0.022 µg I-TEQ/t fuel) for gas/diesel oil and 2.5 µg I-TEQ/TJ (0.1 µg I-TEQ/t fuel) for residual fuel oil. PAH4 and HCB emissions are not estimated from this source. Emissions of SO_2 are calculated from the S-content of the fuels. Emission factors for NOx and CO are taken from Table 1-15 of the revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual. NMVOC emission factor is taken from Table 1.11 in the Reference Manual.

3.3 Manufacturing Industries and Construction (1A2)

3.3.1 Manufacturing Industries, Stationary Combustion

Activity Data

Information about the total amount of fuel used by the manufacturing industries was obtained from the National Energy Authority and adjusted by EA (see Annex I). The total fuel consumption per fuel type can be seen in Table 3.3. The sales statistics for the manufacturing industry (as adjusted by EA) are given for the sector as a total. They do not specify the fuel consumption by the different industrial sources. This division is made by EA on basis of the reported fuel use by all major industrial plants falling under law no. 65/2007 (metal production, cement) and from green accounts submitted by the industry in accordance with regulation 851/2002 for industry not falling under law no. 65/2007. There is thus a given total, which the usage in the different sectors must sum up to. Fuel consumption in the fishmeal industry from 1990 to 2002 was estimated from production statistics, but the numbers for 2003 to 2011 are based on data provided by the industry (application for free allowances under the ETS for the years 2005 to 2010, information from the Icelandic Association of Fishmeal Manufacturers for 2003, 2004 and 2011). The difference between the given total for the sector and the sum of the fuel use of the reporting industrial facilities are categorized as 1A2f other non-specified industry. Emissions

are calculated by multiplying energy use with a pollutant specific emission factor. Emissions from fuel use in the ferroalloys production is reported under 1A2a. Emissions from the cement industry and the mineral wool production are reported under 1A2fi. For PAH4, emissions from the mineral wool production are not estimated, and for dioxin, emissions from the cement industry are reported under industrial processes (2A1).

Table 3.3. Fuel use (kt), stationary combustion in the manufacturing industry.

	1990	1995	2000	2005	2008	2009	2010	2011
Gas/Diesel oil	5.1	1.1	10.3	22.2	8.6	9.8	9.4	4.9
Residual fuel oil	55.9	56.2	46.2	25.0	20.5	17.6	16.5	17.3
LPG	0.5	0.4	0.9	0.9	1.9	1.2	1.0	1.0
Electrodes (residue)	0.8	0.3	1.5	-	0.5	0.4	0.4	-
Steam Coal	18.6	8.6	13.3	9.9	21.5	10.2	3.6	7.8
Petroleum coke	-	-	-	8.1	-	-	-	-
Waste oil	-	5.0	6.0	1.8	2.2	0.9	1.4	1.2

Emission factors

Emission factors for dioxin for liquid fuel used in stationary combustion in manufacturing industry are taken from the Utslipp til luft av dioxiner i Norge (Statistics Norway, 2002). PAH4 emission factors for coal used in stationary combustion (used in the cement industry) as well as the profile ratio are taken from the chapter "An approach to estimation of PAH emission" in the Emission Inventory Guidebook (EEA 2007). The BaP emission factor for industrial coal combustion for large plants is taken from Appendix 3 of the chapter and the profile ratio is found in section 7. PAH emission factors for liquid fuels are taken from table 3-4 (Tier 1 EF for 1A2 combustion in industry using liquid fuels) from Chapter 1.A.2 of the Emission Inventory Guidebook (EEA 2009). The emission factors for dioxin and PAH4 are presented in Table 3.4.

Table 3.4. Emission factors for dioxin and PAH4 from stationary combustion in manufacturing industry

	dioxin [µg I-TEQ/t fuel]	BaP [µg/GJ]	BbF [µg/GJ]	BkF [µg/GJ]	IPy [µg/GJ]
Gas / Diesel Oil	0.1	5.2	6.2	4.0	2.2
Residual fuel oil	0.1	5.2	6.2	4.0	2.2
LPG	0.06	5.2	6.2	4.0	2.2
Electrodes residues	IE*	0.14	PR: 0.05	PR: 0.01	PR: 0.8
Steam Coal	IE*	0.14	PR: 0.05	PR: 0.01	PR: 0.8
Petroleum coke	IE*	5.2	6.2	4.0	2.2
Waste oil	4.0	5.2	6.2	4.0	2.2

* Coal, electrodes residues and petroleum coke are only used in the cement plant; all dioxin emissions from the cement plant are reported under 2A1
PR: profile ratio

SO_2 emissions are calculated from the S-content of the fuels. Source specific emission factors for NOx and CO are taken from Table 1.16 and 1.17 of the revised 1996 IPCC Guidelines for

National Greenhouse Gas Inventories: Reference Manual. Emission factors for NMVOC are taken from Table 1.11 in the Reference Manual. Sulphur emissions from use of petroleum coke occur in the cement industry. Further waste oil has mainly been used in the cement industry. Emission estimates for SO_2 for the cement industry are based on measurements.

3.3.2 Manufacturing Industries, Mobile Combustion

Activity Data

Activity data for mobile combustion in the construction sector is provided by the NEA. Oil, which is reported to fall under vehicle usage, is in some instances actually used for machinery and vice versa as it happens that machinery refuels at a tank station, (thereby reported as road transport), as well as fuel that is sold to contractors, to be used on machinery, is used for road transport (but reported under construction). This is, however, very minimal and the deviation is believed to level out. Emissions are calculated by multiplying energy use with a pollutant specific emission factor. Activity data for fuel combustion are given in Table 3.5.

Table 3.5. Fuel use (kt), mobile combustion in the construction industry.

	1990	1995	2000	2005	2008	2009	2010	2011
Gas/Diesel oil	38.0	46.7	61.9	67.8	59.0	40.7	32.2	27.7

Emission Factors

Emission factors for dioxin from mobile sources are taken from “Utslipp til luft av dioxiner i Norge” (Statistics Norway, 2002). They are 0.1 µg/t fuel. PAH emissions are not estimated from this source. SO_2 emissions are calculated from the S-content of the fuels. Emission factors for NOx, CO and NMVOC are taken from Table 1.49 of the revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual.

3.4 Transport (1A3)

3.4.1 Civil Aviation

Emissions are calculated by multiplying energy use with a pollutant specific emission factor. Emissions from civil aviation are estimated as totals, so landings and take-offs for civil aviation are included in civil aviation – cruise. Landing and take-offs in international aviation are included in international aviation – cruise, and not included in national totals.

Activity Data

Total use of jet kerosene and gasoline is based on the NEA's annual sales statistics for fossil fuels. Activity data for fuel combustion are given in Table 3.6.

Table 3.6. Fuel use (kt), domestic aviation.

	1990	1995	2000	2005	2008	2009	2010	2011
Jet kerosene	8.409	8.253	7.728	7.390	7.601	6.271	6.066	6.027
Gasoline	1.681	1.131	1.102	0.872	0.731	0.649	0.648	0.411

Emission Factors

Emission factors for dioxin are taken from the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP 2005) and from "Utslipp til luft av dioxiner i Norge" (Statistics Norway, 2002). PAH4 emissions are not estimated. SO_2 emissions are calculated from the S-content of the fuels. Emission factors for NOx, CO and NMVOC are taken from tables 1.9 to 1.11 from the revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual. The emission factors are presented in Table 3.7.

Table 3.7. Emission factors for dioxin, NOx, CO and NMVOC, aviation

	dioxin [µg I-TEQ/t fuel]	NOx [kg/TJ]	CO [kg/TJ]	NMVOC [kg/TJ]
Jet Kerosene	0.06 [2]	300	100	50
Aviation gasoline	2.2 [1]	300	100	50

[1] UNEP 2005, [2] Statistics Norway 2002

Planned Improvements

Planned improvements involve moving emission estimates from aviation to the Tier 2 methodology by next submission and deviate between cruise and landing/take-off emissions.

3.4.2 Road Vehicles

Emissions from Road Traffic are estimated by multiplying the fuel use by type of fuel and vehicle, and fuel and vehicle pollutant specific emission factors.

Activity Data

Total use of diesel oil and gasoline are based on the NEA's annual sales statistics for fossil fuels (Table 3.8.).

Table 3.8. Fuel use (kt), road transport.

	1990	1995	2000	2005	2008	2009	2010	2011
Gasoline	127.812	135.601	142.599	156.730	155.115	154.932	148.214	142.688
Diesel oil	36.567	36.862	47.463	83.478	113.964	114.491	106.433	106.293

NEA estimates on how the fuel consumption is divided between different vehicles groups, i.e. passenger cars, light duty vehicles, and heavy duty vehicles are used for the period 1990 to 2005. From 2006 to 2011 EA estimated how the fuel consumption is divided between the different vehicles groups, using information on the number of vehicles in each group and the driven mileage in each group from the Road Traffic Directorate, using average fuel consumption based on the 1996 IPCC Guidelines regarding average fuel consumption per

group. The data for 2006 to 2011 also contains information on motorcycles. The Road Traffic Directorate is working on providing similar data for previous years along with average fuel consumption per group. This work was not finished in time for this submission, but will hopefully be included in next submission. Therefore the time series is not fully consistent as two different methodologies are used. For the years 1990 to 2006 emissions from motorcycles are included in emissions from other vehicles.

The EA has estimated the amount of passenger cars by emission control technology. The proportion of passenger cars with three-way catalysts has steadily increased since 1995 when they became mandatory in all new cars. The assumptions are shown in Figure 3.1. Although three-way catalysts have been mandatory for a long time now, it is assumed that the proportion of cars with three-way catalyst stagnates at 86%, as the catalysts usually lose their function after about 10 years.

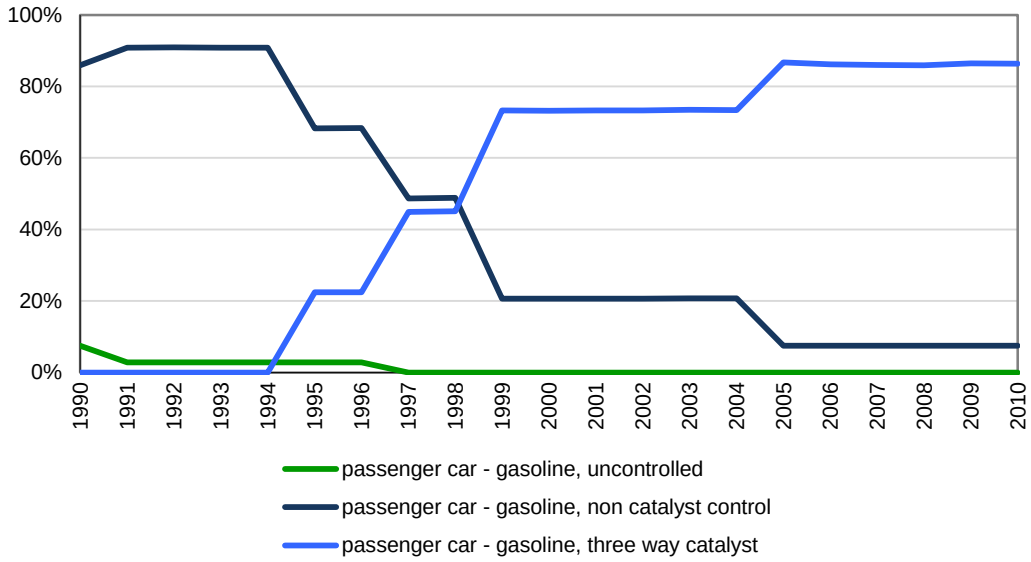

Figure 3.1. Passenger cars by emission control technology.

Emission Factors

Emission factors for dioxin are taken from the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP 2005). They are presented in Table 3.9. Emission factor PAH are taken from the chapter "An approach to estimation of PAH emission" in the Emission Inventory Guidebook (EEA 2007). Emission factors for PAH4 are presented in Table 3.10.

Table 3.9. Emission factors for dioxin, road vehicles

	dioxin [µg I-TEQ/t fuel]
Gasoline, leaded	2.2
Gasoline, unleaded, no catalyst	0.1
Gasoline, unleaded, with catalyst	0
Gas / Diesel Oil	0.1

Table 3.10. Emission factors for PAH4, road vehicles

	B[a]P [µg/km]	Fuel cons. [L/100 km]	B[a]P µg/kg fuel	ratio to B[a]P		
				B[b]F	B[k]F	I[cd]P
pass.cars gasoline - conventional	1.1	10	14.86	1.2	0.9	1
pass.cars gasoline - catalyst	0.4	10	5.41	0.9	1.2	1.4
light duty vehicles - gasoline	1.1	10	14.86	1.2	0.9	1
pass.cars diesel - direct inj.	0.7	13	6.49	0.9	1	1.1
pass.cars diesel - indirect inj.	2.8	13	25.95	0.9	0.8	0.9
light duty vehicles diesel - direct inj.	0.7	13	6.49	0.9	1	1.1
light duty vehicles diesel - indirect inj.	2.8	13	25.95	0.9	0.8	0.9
HDV (diesel)	1	26	4.63	5.6	8.2	1.4
other use, gas/diesel oil, (HDV)	1	26	4.63	5.6	8.2	1.4

SO_2 emissions are calculated from the S-content of the fuels. Emission factors for other pollutants depend upon vehicle type and emission control. They are taken from tables 1.36 to 1.42 of the revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories and are presented in Table 3.11.

Table 3.11. Emission factors for NOx, CO and NMVOC for European vehicles.

	NOx [g/kg fuel]	CO [g/kg fuel]	NMVOC [g/kg fuel]
Passenger car – gasoline, uncontrolled	27	550	63
Passenger car – gasoline, non-catalyst control	37	300	72
Passenger car – gasoline, three way catalyst	8.2	45.9	7.1
Light duty vehicle – gasoline	29	360	59
Heavy duty vehicle – gasoline	40	346	32
Motorcycles - gasoline	2.7	730	530
Passenger car – diesel	11	12	3
Light duty vehicle – diesel	16	18	4.6
Heavy duty vehicle – diesel	42	36	8

Planned Improvements

Planned improvements involve getting more comprehensive data regarding the fleet composition, mileage driven and fuel consumption from the Road Traffic Directorate for all years and in the near future estimating emissions from road transport with the COPERT model.

3.4.3 National Navigation

Emissions are calculated by multiplying energy use with a pollutant specific emission factor.

Activity Data

Total use of residual fuel oil and gas/diesel oil for national navigation is based on NEA's annual sales statistics for fossil fuels. Activity data for fuel combustion are given in Table 3.12.

Table 3.12. Fuel use (kt), national navigation.

	1990	1995	2000	2005	2008	2009	2010	2011
Gas/Diesel oil	11.749	7.043	3.425	6.199	13.179	6.270	8.464	5.523
Residual fuel oil	7.170	4.755	0.542	0.881	4.192	3.709	2.612	0.330

Emission Factors

Emission factors for dioxin and PAH (only BbF) are taken from Utslipp til luft av dioxiner i Norge (Statistics Norway, 2002). They are presented in Table 3.13.

Table 3.13. Emission factors for dioxin and BbF, navigation

	dioxin [µg I-TEQ/t fuel]	BbF [g BbF/t fuel]	NOx [kg/TJ]	CO [kg/TJ]	NMVOC [kg/TJ]
Gas / Diesel Oil, on ocean	4	0.04	1800	180	52
Residual fuel oil, on ocean	4	0.04	1800	180	52

SO_2 emissions are calculated from the S-content of the fuels. Emission factors for NOx, CO and NMVOC are taken from Table 1.48 in the revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories for ocean-going ships. They are also presented in Table 3.13.

3.4.4 Commercial, Institutional, and Residential Fuel Combustion (1A4a, 1A4b)

Since Iceland relies largely on its renewable energy sources, fuel use for residential, commercial, and institutional heating is low. Residential heating with electricity is subsidized and occurs in areas far from public heat plants. Two incineration plants use waste to produce heat. One of them uses the heat for heating a swimming pool and a school building (Skaftárhreppur), and the other one uses the heat for heating a swimming pool (Svínafell). That plant was closed down in 2010. Commercial/institutional fuel combustion includes the heating of swimming pools with gas oil, but only a few swimming pools in the country are heated with oil. Two swimming pools and a school building are heated with heat from waste incineration plants. The resulting emissions are reported here.

Activity Data

Activity data for fuel use is provided by the NEA, which collects data on fuel sales by sector. EA adjusts the data provided by the NEA as further explained in Annex I. Activity data for waste incineration are collected by EA directly. Activity data for fuel combustion and waste incineration in the Commercial/Institutional sector are given in Table 3.14.

Table 3.14. Fuel use (kt), commercial/institutional sector.

	1990	1995	2000	2005	2008	2009	2010	2011
Gas/Diesel oil	1.8	1.6	1.6	1.0	0.3	0.3	0.3	0.3
Waste oil	3.3	-	-	-	-	-	-	-
LPG	0.3	0.3	0.5	0.5	0.1	0.1	0.2	0.2
Solid waste	-	0.5	0.6	0.6	0.4	0.3	0.3	0.2

Activity data for fuel combustion in the Residential sector are given in Table 3.15. As can be seen in the table the use of kerosene has increased substantially the last four years. Kerosene is used in summerhouses but also, to some extent, in the Commercial sector for heating of commercial buildings. The usage has been very low over the years and therefore the kerosene utilisation has all been allocated to the Residential sector. The increase in usage in the years 2008 to 2011 is believed to be attributed to rapidly rising fuel prices for the Transport sector. This has motivated some diesel car owners to use kerosene on their cars as the kerosene does not have CO_2 tax, despite the fact that it is not good for the engine.

Table 3.15. Fuel use (kt), residential sector.

	1990	1995	2000	2005	2008	2009	2010	2011
Gas/Diesel oil	8.8	6.4	6.0	3.2	2.0	2.1	1.9	1.4
LPG	0.4	0.5	0.7	0.9	1.1	1.6	1.4	0.7
Kerosene	0.5	0.2	0.1	0.2	0.8	4.0	1.2	3.2

Emission Factors

Emission factors for dioxin from stationary combustion are taken from from Utslipp til luft av dioxiner i Norge (Statistics Norway, 2002). They are 0.1 µg/t fuel for gas oil and kerosene, 0.06 µg/t fuel for LPG and 4 µg/t for waste oil. Emissions of SO_2 are calculated from the S-content of the fuels. Emission factors for other pollutants are taken from Table 1.18 and 1.19 of the revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual. Default EFs from Tables 1.7 to 1.11 in the Reference Manual were used in cases where EFs were not available. Emissions from waste incineration with recovery, where the energy is used for swimming pools/school buildings are reported here. A description of the method for calculating GHG is provided in Chapter 7. The IEF for dioxin in the sector shows fluctuations over the time series. From 1994 onwards waste has been incinerated to produce heat at two locations (swimming pools, school building). The IEF for dioxin for waste is considerably higher than for liquid fuel. Further waste oil was used in the sector from 1990 to 1993. This combined explains the rise in IEF for the whole sector.

3.4.5 Agriculture, Forestry, and Fishing (1A4c)

Emissions from fuel use in agriculture and forestry are included elsewhere, mainly within the construction (1A2fii) and Residential sectors (1A4bi); thus, emissions reported here only stem from the fishing fleet. Emissions from commercial fishing are calculated by multiplying energy use with a pollutant specific emission factor.

Activity Data

Total use of residual fuel oil and gas/diesel oil for the commercial fishing is based on the NEA's annual sales statistics for fossil fuels. Activity data for fuel combustion in the Fishing sector are given in Table 3.16.

Table 3.16. Fuel use (kt), fishing sector.

	1990	1995	2000	2005	2008	2009	2010	2011
Gas/Diesel oil	174.9	191.3	211.1	171.7	127.7	144.7	128.2	120.1
Residual fuel oil	32.4	53.4	16.0	26.3	36.3	44.6	41.4	38.5

Emission Factors

Emission factors for dioxin and PAH (only BbF) are taken from Utslipp til luft av dioxiner i Norge (Statistics Norway, 2002). They are presented in Table 3.13. SO_2 emissions are calculated from the S-content of the fuels. Emission factors for other pollutants are taken from Table 1.48 in the revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories for ocean-going ships. They are also presented in Table 3.13.

3.5 International Bunker Fuels

Emissions from international aviation and marine bunker fuels are excluded from national totals in line with the reporting guidelines under the UNFCCC. Emissions are calculated by multiplying energy use with pollutant specific emission factors.

Activity data is provided by the NEA, which collects data on fuel sales by sector. This data distinguish between national and international usage. In Iceland there is one main airport for international flights, Keflavík Airport. Under normal circumstances almost all international flights depart and arrive from Keflavík Airport, except for flights to Greenland, the Faroe Islands, and some flights with private airplanes which depart/arrive from Reykjavík airport. Domestic flights sometimes depart from Keflavík airport in case of special weather conditions. Oil products sold to Keflavík airport are reported as international usage. The deviations between national and international usage are believed to level out. Emissions estimates for aviation will be moved to Tier 2 methodology by next submissions. A better methodology for the fuel split between international and domestic aviation will be developed in the near future as Iceland takes part in the EU ETS for aviation from 2012 onward and better data will become available. Emission factors for aviation bunkers are the same as described for domestic aviation.

The retail supplier divides fuel use between international navigation (including foreign fishing vessels) and national navigation based on identification numbers which differ between Icelandic and foreign companies. The emission factors for marine bunkers are the same as described for national navigation.

3.6 Fugitive emissions

3.6.1 Distribution of oil products (1B2a v)

NMVOC emissions from distribution of oil products are estimated by multiplying the total imported fuel with an emission factor. The emission factor is taken from the Emission Inventory Guidebook (EEA, 2009) and is 9 kg/Mg. Data on total import of fuels are taken from Statistics Iceland.

3.6.2 Geothermal Energy (1B2d)

Iceland relies heavily on geothermal energy for space heating (90%) and to a significant extent for electricity production (27% of the total electricity production in 2011). Geothermal energy is generally considered to have relatively low environmental impact. Emissions of CO_2 are commonly considered to be among the negative environmental effects of geothermal power production, even though they have been shown to be considerably less extensive than from fossil fuel power plants, or 19 times less (Baldvinsson et al., 2011). Very small amounts of methane but considerable quantities of sulphur in the form of hydrogen sulphide (H_2S) are emitted from geothermal power plants.

Methodology

The H_2S concentration in the geothermal steam is site and time-specific, and can vary greatly between areas and the wells within an area as well as by the time of extraction. The total emissions estimate of H_2S is based on direct measurements. The enthalpy and flow of each well are measured and the H_2S concentration of the steam fraction determined at the wellhead pressure. The steam fraction of the fluid and its H_2S concentration at the wellhead pressure and the geothermal plant inlet pressure are calculated for each well. Information about the period each well discharged in each year is then used to calculate the annual H_2S discharge from each well and finally the total H_2S is determined by adding up the H_2S discharge from individual wells.

Table 3.17. shows the electricity production with geothermal energy and the total sulphur emissions (calculated as SO_2).

Table 3.17. Electricity production and emissions from geothermal energy in Iceland.

	1990	1995	2000	2005	2008	2009	2010	2011
Electricity production (GWh)	283	288	1323	1658	4037	4553	4465	4701
Sulphur emissions (as SO_2, Gg)	13.3	11.0	26.0	30.0	58.9	52.8	57.7	64.5

4 Industrial processes

The industrial process sector is important for emissions of dioxins, HCB and PAH4 as well as other pollutants; PAH4 from metal production in particular. Due to the expansion of energy intensive industry, emissions have increased rapidly since 1996. The main category within the industrial process sector is metal production. The location of operating industrial facilities in 2011 is shown in Figure 4.1.

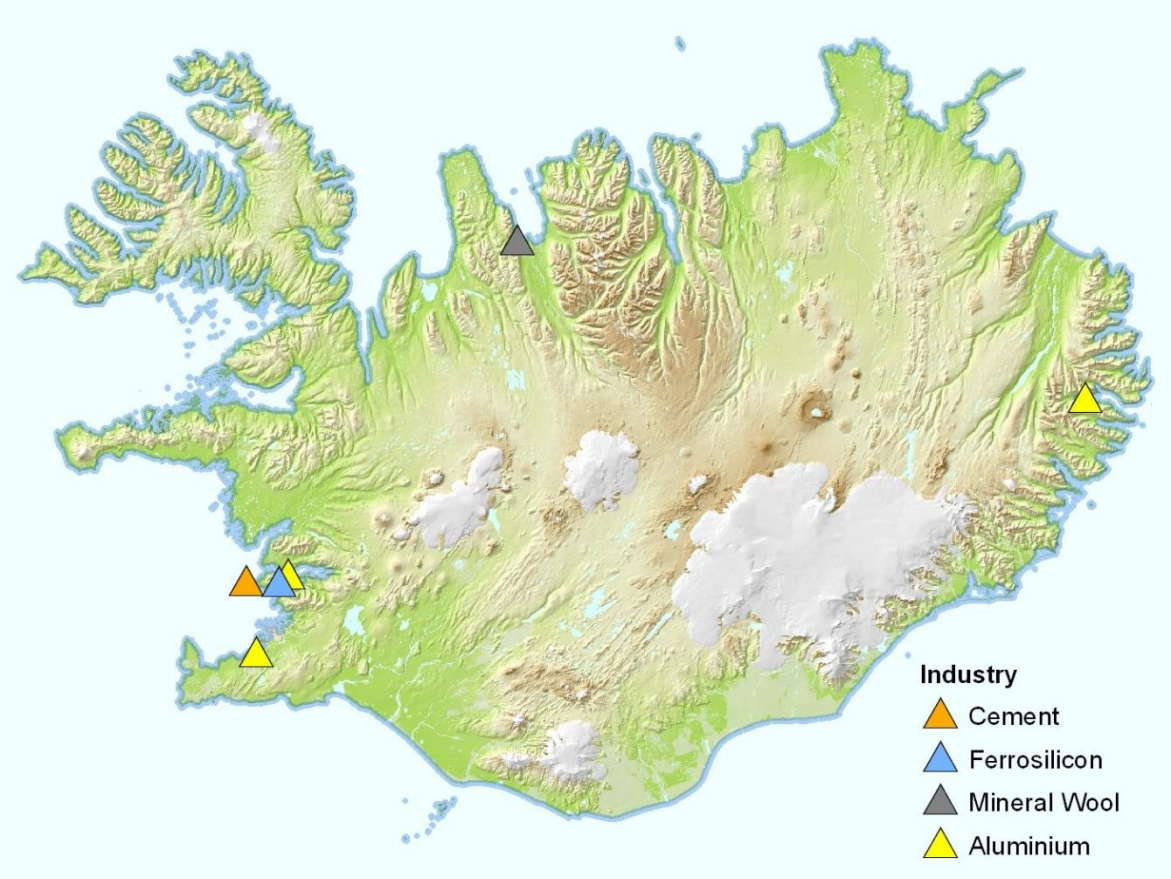

Figure 4.1. Location of industrial facilities in 2011.

4.1 Mineral Industry (2A)

4.1.1 Cement Production

The single operating cement plant in Iceland produces cement from shell sand and rhyolite in a rotary kiln using a wet process. The raw material calcium carbonate, which comes from shell sand, is calcinated in the production process. The resulting calcium oxide is heated to form clinker and then crushed to form cement.

Activity data

Process specific data on cement production, clinker production and amounts of coal are collected by the EA directly from the cement production plant.

Emission factors

Emission factor for dioxin is taken from the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP 2005). The factor applies for wet kilns, with ESP/FF temperature < 200°C and is 0.05 µg I-TEQ/t cement. The HCB emission factor is taken from the chapter Sources of HCB emissions from the Emission Inventory Guidebook (EEA, 2007). Emissions of PAH, NOx, CO and NMVOC originate mainly from combustion and are reported under 1A2fi. Emission estimates for SO_2 are based on measurements.

4.1.2 Road Paving with Asphalt

Asphalt road surfaces are composed of compacted aggregate and asphalt binder. Gases are emitted from the asphalt plant itself, the road surfacing operations, and subsequently from the road surface. Information on the amount of asphalt produced comes from Statistics Iceland. The emission factors for NMVOC are taken from Table 3.1, from Chapter 2.A.6 in the EMEP/EEA emission inventory guidebook (EEA, 2009). Emissions of SO_2, NO_x, and CO are expected to originate mainly from combustion and are therefore not estimated here but accounted for under sector 1A2f.

4.1.3 Mineral Wool Production

Emissions of dioxins are calculated from the amount of electrodes used in the production process. The emission factor is taken from Utslipp til luft av dioxiner i Norge (Statistics Norway, 2002) and is 1.6 µg I-TEQ/t electrodes. PAH emissions are not estimated. Emissions of SO_2 are based on S-content of the elctrodes used. Emissions of CO are based on measurements. NOx and NMVOC emissions originate from combustion and are reported under sector 1A2f.

4.2 Chemical industry (2B)

The only chemical industry that has existed in Iceland is the production of silicium and fertilizer. The fertilizer production plant was closed down in 2001 and the silicium production plant was closed down in 2004. This industry is not considered to be a source of dioxins or PAHs.

At the silicium production plant, silicium containing sludge was burned to remove organic material. Emissions of CO_2 and NO_x were estimated on the basis of the C-content and N-content of the sludge. Emissions also occur from the use of soda ash in the production process and those emissions are reported here.

When the fertilizer production plant was operational it reported its emissions of NO_x and N_2O to the EA.

4.3 Metal Production (2C)

4.3.1 Ferroalloys

Ferrosilicon (FeSi, 75% Si) is produced at one plant in Iceland. The raw material is quartz (SiO_2). The quartz is reduced to Si and CO using reducing agents. The waste gas CO and some SiO burns to form CO_2 and silicia dust. In the production raw ore, carbon material and slag forming materials are mixed and heated to high temperatures for reduction and smelting. Ready-to-use iron pellets for the production are imported so no additional emissions occur from the iron part of the FeSi production. The carbon materials used are coal, coke and wood. Electric (submerged) arc furnaces with Soederberg electrodes are used. The furnaces are semi-covered. Emissions originate from the use of coal and coke as reducing agent, as well as from consumption of electrodes. Waste gases are cleaned via dry absorption units (bag-house filters). When the temperature inside the units gets too high, emergency bypass of the bag-house filters is induced. The operating permit of the Elkem ferrosilicon plant contains provisions on the maximal duration of such incidences (in percent over the year).

Activity data

The consumption of reducing agents and electrodes are collected by the EA directly from the single operating ferroalloys production plant. Further information on total production is given.

Emission factors

In 2011 emissions of dioxin and PAH4 (each component was measured) were measured at the Ferrosilicon plant. These measurements were used to obtain plant specific emission factors per tonne of production that were used for the whole time series. They are presented in Table 4.1.

Emission factor for CO is 1.62 kg/t FeSi and is taken from table 2.16 and emission factors for NOx and NMVOC are taken from table 1.9 and 1.11 of the revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference manual. Sulphur emissions are calculated from S-content of the reducing agents. Emission factors are presented in Table 4.1.

Emissions of particulates are calculated by adding up the emissions from filtered exhaust and the amount of particulates that are released during emergency bypass of the exhaust. Emission factor for filtered exhaust is taken fromTable 9.9 in “Reference document on Best Available Techniques in the Non Ferrous Metals Industries”. It is 5 mg/Nm^3. This factor is then multiplied with the plant specific yearly amount of exhaust (in Nm^3). To calculate the bypass emissions, first the total Microsilica, fine (collected and sold e.g. to cement producers) and coarse (cyclone dust) are added up and divided by the hours per year (8760) to get Microsilica production rate per hour. This is known for all years since 2005. The production rate is then multiplied with the bypass time per furnace and the ratio of the FeSi production per furnace of the total FeSi production each year. The bypass rate is known

since 2002 and taken from Green Accounts, submitted in accordance with Regulation 851/2002. The bypass rate for previous years was calculated as the average of the years 2002 to 2006. Microsilica (fine and coarse) production rate and production per furnace were extrapolated for the years 1990 to 2001 based on total produced FeSi at the plant each year.

Table 4.1. Emission factors for dioxin, PAH4, NOx and NMVOC from ferroalloys production

	dioxin [µg/t FeSi]	BaP [mg/t FeSi]	BbF [mg/t FeSi]	BkF [mg/t FeSi]	IPy [mg/t FeSi]	NOx [kg/TJ]	NMVOC [kg/TJ]
FeSi	0.114	2.790	102.221	29.677	9.385	-	-
Coal	-	-	-	-	-	300	20
Coke	-	-	-	-	-	300	20
Charcoal	-	-	-	-	-	300	20
Waste wood	-	-	-	-	-	100	50
Electrodes	-	-	-	-	-	300	20

4.3.2 Primary Aluminium Production

In 2011 aluminium was produced at 3 plants in Iceland. Best Available Technology (BAT) is used at all plants, i.e. closed prebake systems with point feeding of alumina, efficient process control, hoods covering the entire pot and efficient collection of air pollutants.

Primary aluminium production results in emissions of dioxins, PAH4, NOx, particulates and SO_2. Emissions originate from the consumption of electrodes during the electrolysis process.

Activity data

The EA collects annual process specific data from the three operating aluminium plants. The total production of the three aluminium plants is given in Table 4.13.

Emission factors

In 2011 emissions of dioxin were measured at the aluminium plants. At one plant PAH4 was also measured. The same plant also measured PAH4 in 2002. For PAH4 average emission factors from these two measurements were calculated. The measurements were used to obtain plant specific emission factors per tonne of production that were used for the whole time series. Of the total pot gases 98.5 % are collected and cleaned via dry adsorption unit. Thus, 1.5% of the pot gases leak unfiltered to the atmosphere. Both dioxin and PAH4 are practically non-existent in the cleaned gas (below detection limit). Emission factors are derived from the concentration of dioxin and PAH4 in the raw gas. They are presented in Table 4.12.

NOx is calculated by using the emission factor of 1 kg/t aluminium that is taken from the Emission Inventory Guidebook (EEA, 2009). Particulate matter was calculated from information on particulates per tonne of produced aluminium that the aluminium plants report in their green accounts submitted by in accordance with regulation 851/2002. NOx

and particulates were estimated for the first time in this submission. Emissions of SO_2 are estimated from S-content of alumina and electrodes.

Table 4.2. Emission factors for dioxin, PAH4 and NOx from aluminium production

	NOx [kg/t]	dioxin [µg/t Al]	PAH4 [mg/t Al]	BaP % of PAH4	BbF % of PAH4	BkF % of PAH4	IPy % of PAH4
Al	1	0.0329	0.0189	13%	61%	18%	8%

Table 4.3. Aluminium production, tonnes.

	1990	1995	2000	2005	2008	2009	2010	2011
Production	87,839	100,198	226,362	272,488	781,151	817,281	818,859	806,319

4.3.3 Secondary Aluminium Production

In 2004 a secondary aluminium production plant was established in Iceland. The plant recycles scrap aluminium from the two primary aluminium plants in southwest of Iceland (in 2011 only from one plant). The scrap metal is melted in batches in a rotary kiln. Emissions of dioxin and HCB are estimated. Activity data is taken from green accounts. The dioxin emission factor comes from the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP 2005). The lowest value (0.5 µg/t aluminium) for secondary aluminium production was chosen as the plant only recycles scrap metal from primary aluminium plants and no coated aluminium, so organic compounds in the input material is minimum. Also no chlorine is added in the process and further oxy-fuel burners are used. The HCB emission factor (5 g/t) is taken from the chapter Sources of HCB emissions from the Emission Inventory Guidebook (EEA, 2007). Measurements of dioxin at the plant in 2012, showed that the EF of 0.5 µg/t represents the plant well.

Activity data are presented in Table 4.1.

Table 4.4. Secundary aluminium production.

	2004	2005	2006	2007	2008	2009	2010	2011
Production [ktonnes]	2.36	2.25	2.31	2.28	2.47	3.05	2.04	1.0

4.4 Other Production (2D)

Other production in Iceland is the Food and Drink Industry. NMVOC emissions from this sector were estimated for the first time in last submission. Production statistics were obtained by Statistics Iceland for beer, fish, meat and poultry for the whole time series (Figure 4.2). Statistics for coffee roasting and animal feed were available for the years 2005 to 2011. Production statistics were extrapolated for the years 1990 to 2004. For this submission production statistic for fish, meat and poultry were revised. Further production

of bread, cakes and biscuits was estimated from consumption figures. Emission factor for NMVOC were taken from Tables 2-24 and 2-25 in the 1996 IPCC Guidelines.

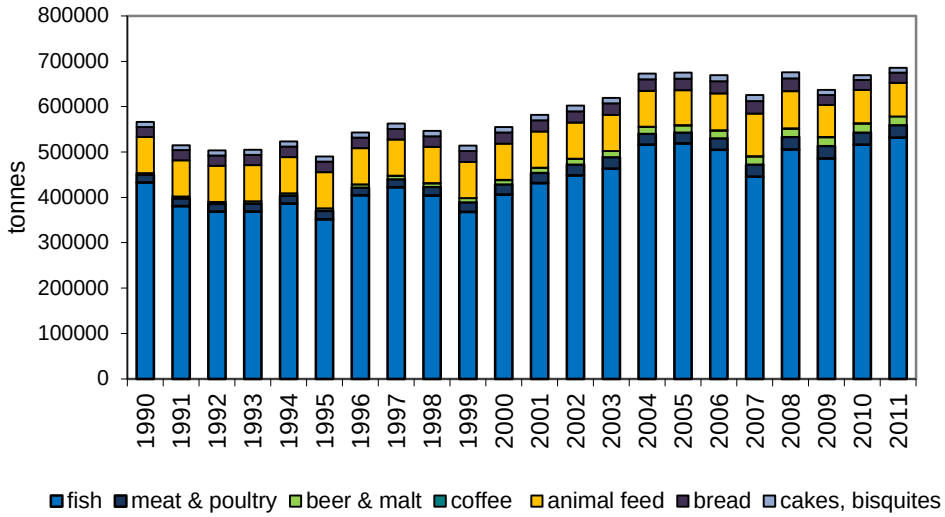

Figure 4.2. Food and drink production.

5 Solvent and other product use

This chapter describes mainly non-methane volatile organic compounds (NMVOC) emissions from solvents. When volatile chemicals are exposed to air, emissions are produced through evaporation of the chemicals. The use of solvents and other organic compounds in industrial processes and households is important source NMVOC evaporation. Emissions of other pollutants than NMVOC only stem from other use of products, sector 3D3, namely from preservation of wood and use of tobacco.

Methodology

NMVOC emissions are estimated according to the EMEP/EEA air pollutant emission inventory guidebook (EEA, 2009).

Source Specific QA/QC Procedures

The QC activities include general methods such as accuracy checks on data acquisition and calculations as well as the use of approved standardised procedures for emission calculations, estimating uncertainties, archiving information and reporting. Further information can be found in the QA/QC manual.

5.1 Paint application (3A)

Methodology, activity data and emission factors

The categories Paint application, Degreasing, and Other NMVOC emissions from printing and other product use have in common that their activity data consists of data about imported goods. This data was received from Statistics Iceland.

The EMEP guidebook (EEA, 2009) provides emission factors based on amounts of paint applied. Data exists on imported paint since 1990 (Statistics Iceland, 2012) and on domestic production of paint since 1998 (Icelandic recycling fund, 2012). The Tier 1 emission factor refers to all paints applied, e.g. waterborne, powder, high solid and solvent based paints. The existing data on produced and imported paints however, makes it possible to narrow activity data down to conventional solvent based paints. Therefore Tier 2 emission factors for conventional solvent based paints could be applied. The activity data does not allow for a distinction between decorative coating application for construction of buildings and domestic use of paints. Their NMVOC emission factors, however, are identical: 230 g/kg paint applied. It is assumed that all paint imported and produced domestically is applied domestically during the same year. Therefore the total amount of solvent based paint is multiplied with the emission factor. For the time before 1998 no data exists about the amount of solvent based paint produced domestically. Therefore the domestically produced paint amount of 1998, which happens to be the highest of the time period for which data exists, is used for the period from 1990-1997. The amounts of solvent based paint produced domestically and imported are shown in Figure 5.1.

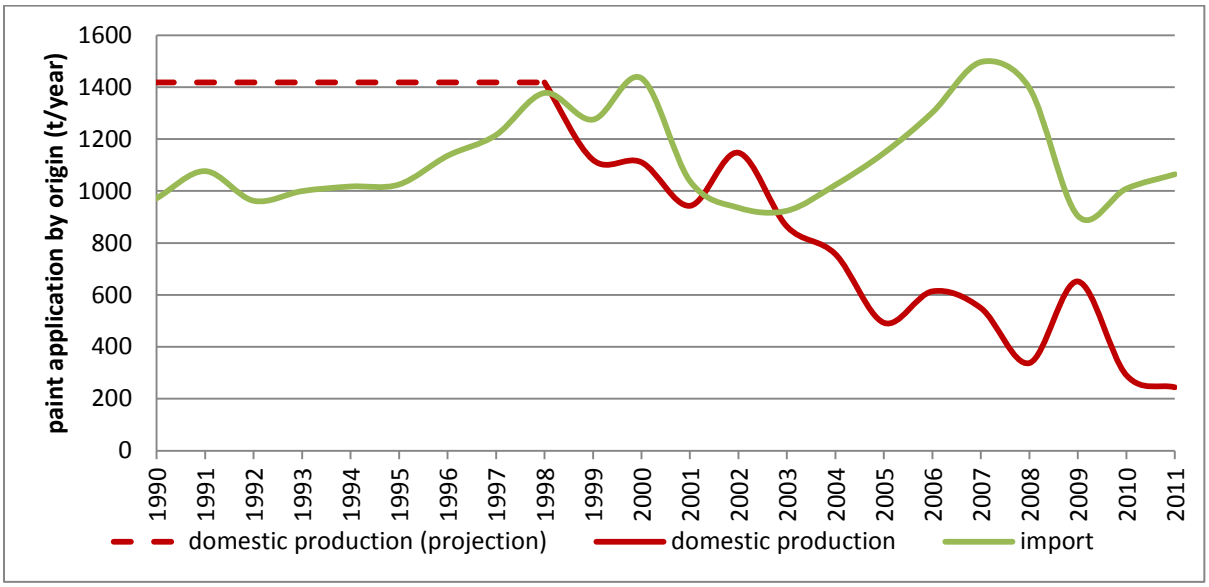

Figure 5.1. Amounts of solvent based paints imported and produced domestically

5.2 Degreasing and dry cleaning (3B)

Methodology, activity data and emission factors

The EMEP guidebook provides a Tier 1 emission factor for degreasing based on amounts of cleaning products used. There is data on the amount of cleaning products imported provided by Statistics Iceland. Of the chemicals listed by the EMEP guidebook, activity data is available for: methylene chloride (MC), tetrachloroethylene (PER), trichloroethylene (TRI) and xylenes (XYL). In Iceland, though, PER is mainly used for dry cleaning (expert judgement). In order to estimate emissions from degreasing more correctly without underestimating them, only half of the imported PER was allocated to degreasing. Emissions from dry cleaning are estimated without using data on solvents used (see below). The use of PER in dry cleaning, though, is implicitly contained in the method. In Iceland, xylenes are mainly used in paint production (expert judgement). In order to estimate emissions from degreasing more correctly without underestimating them, only half of the imported xylenes were allocated to degreasing. Emissions from paint production are estimated without using data on solvents used but xylene use is implicitly contained in the method. In addition to the solvents mentioned above, 1,1,1,- trichloroethylene (TCA), now banned by the Montreal Protocol, is added for the time period during which it was imported and used. Another category included is paint and varnish removers. The amount of imported solvents for degreasing was multiplied with the NMVOC Tier 1 emission factor for degreasing: 460 g/kg cleaning product.

Emissions from dry cleaning were calculated using the Tier 2 emission factor for open-circuit machines provided by the EMEP guidebook. Activity data for calculation of NMVOC emissions is the amount of textile treated annually, which is assumed to be 0.3 kg/head (EMEP guidebook default) and calculated using demographic data. The NMVOC emission factor for open-circuit machines is 177g/kg textile treated. Since all dry cleaning machines used in Iceland are conventional closed-circuit PER machines, the emission factor was

reduced using the respective EMEP guidebook reduction default value of 0.89. NMVOC emissions from dry cleaning were calculated thus:

$$E_{NMVOC}\,(t) = \text{population}\,(t) \bullet 0.3 \bullet (177/1000) \bullet (1\text{-}0.89)$$

Where:
E_{NMVOC} (t) = emissions of NMVOC in year t, kg
Population (t) = population in year t
0.3 = amount of textiles treated inhabitant/year, kg
177 = g NMVOC emissions/kg textile treated
0.89 = abatement efficiency of closed circuit PER machines

5.3 Chemical products (3C)

Methodology, activity data and emissions

The only activity identified for the subcategory chemical products, manufacture and processing is manufacture of paints. NMVOC emissions from asphalt blowing, included in the EMEP guidebook under chemical products, are covered in the industry sector (not occurring in Iceland). NMVOC emissions from the manufacture of paints were calculated using the EMEP guidebook Tier 2 emission factor of 11 g/kg product. The activity data consists of the amount of paint produced domestically as discussed above in chapter 5.1.

5.4 Other product use (3D)

5.4.1 Printing

NMVOC emissions for printing were calculated using the EMEP guidebook Tier 1 emission factor of 500g/kg ink used. Import data on ink was received from Statistics Iceland (Statistics Iceland, 2012).

5.4.2 Other domestic use of solvents

NMVOC emissions from other domestic use were calculated using the EMEP guidebook emission factor of 1 kg/inhabitant/year.

5.4.3 Other product use

Wood preservation

Wood is preserved to protect it against fungal and insect attack and also against weathering. There are three main types of preservative: creosote, organic solvent-based (often referred to as 'light organic solvent-based preservatives (LOSP)') and water borne. Creosote is oil prepared from coal tar distillation. Creosote contains a high proportion of aromatic compounds such as polycyclic aromatic hydrocarbons (PAHs). Activity data consists of annual import of creosotes and the assumption that all imported creosote is applied during the year of import. Emission factors for PAH are taken from chapter 3.D.3 of the Emission Inventory Guidebook (EEA, 2009). They are 0.5 mg BaP per kilogramme of creosote, 0.25 mg per kilogramme creosote of the other 3 PAH: BbF, BkF and IPy. NMVOC emissions from wood preservation were calculated using the EMEP guidebook Tier 2 emission factors for creosote preservative type (110 g/kg creosote) and organic solvent borne preservative (900 g/kg

preservative). Import data on both wood preservatives was received from Statistics Iceland (Statistics Iceland, 2012).

Use of tobacco (smoking)

Tobacco smoking is a minor source of dioxins, PAH and other pollutants. Activity data consists of all smoking tobacco imported and is provided by Statistics Iceland (Statistics Iceland, 2012). Emissions factor are taken from table 3-9 in chapter 3.D.3 in the Emission Inventory Guidebook (EEA, 2009). They are presented in Table 5.1.

Table 5.1. Emission factors from tobacco smoking

	dioxin [ng I-TEQ/t]	PAH4 [mg/t]	NOx [g/t]	CO [g/t]	NMVOC [g/t]
Tobacco	1.3	0.04	3.5	122	4.8

6 Agriculture

Icelanders are self-sufficient in all major livestock products, such as meat, milk, and eggs. Traditional livestock production is grassland based and most farm animals are native breeds, i.e. dairy cattle, sheep, horses, and goats, which are all of an ancient Nordic origin, one breed for each species. These animals are generally smaller than the breeds common elsewhere in Europe. Beef production, however, is partly through imported breeds, as is most poultry and all pork production. There is not much arable crop production in Iceland, due to a cold climate and short growing season. Cropland in Iceland consists mainly of cultivated hayfields, but barley and rapeseed are grown on limited acreage.

Ammonia, nitric oxide, and particulate matter emissions are estimated for animal husbandry and manure management (4.B) as well as Crop production and agricultural soils (4.D). NMVOC emissions are estimated solely for 4.D. Hexachlorocyclohexane emissions are estimated for Agriculture other (4.G)

Source Specific QA/QC Procedures

The QC activities include general methods such as accuracy checks on data acquisition and calculations as well as the use of approved standardised procedures for emission calculations, estimating uncertainties, archiving information and reporting. Further information can be found in the QA/QC manual.

6.1 Animal husbandry and manure management (4.B)

6.1.1 Methodology

Methodology is based on chapter 4.B of the EMEP/EEA air pollutant emission inventory guidebook (EEA, 2009) and all equations as well as the majority of emission factors and other parameters stem from the guidebook chapter. For brevity the guidebook will be referred to as the EMEP GB. Equations and parameters will not be listed in this chapter. Instead it is referred to the respective places in 4.B of the EMEP GB.

Ammonia, nitric oxide, PM_{10} and $PM_{2.5}$ emissions are estimated with Tier 2 methods. Tier 2 for ammonia and nitric oxide uses a mass flow approach which is based on the flow of total ammoniacal N (TAN) through the manure management system. In the EMEP GB this flow is modelled by a series of equations (pp. 20-25). The set of equations provided by the EMEP GB was applied to more disaggregated livestock categories than the NFR methodology demands (e.g. mature ewes, rams, animals for replacement, and lambs instead of just sheep). The resulting emissions were then aggregated to the respective NFR categories. NH_3 emissions from grazing animals are part of this process and therefore calculated in this context but reported under agricultural soils (4.D). Activity data, emission factors and other parameters used in these calculations will be discussed in the following chapters. Tier 2 methodology for PM emissions consists of the multiplication of livestock populations with default emission factors for slurry and solid manure applied to the time animals spent in housing.

6.1.2 Activity data and emission factors

All emission estimates in 4.B depend on annual average populations (AAP) of livestock categories. Data on livestock population comes from a census conducted by the Icelandic Food and Veterinary Agency (IFVA). Since this data represents livestock populations at a certain point in time (during winter) it does not reflect their seasonal changes, e.g. animals with a life spanning only one summer. Also, for some livestock categories, it does not include data on young animals, e.g. fattening pigs. Therefore, the number of animals not included in the census is estimated using information on fertility rates, number of offspring, number of animals slaughtered, etc. When calculating the AAP of livestock categories the amount of livestock with a lifespan of less than one year is weighted with its respective lifespan, e.g. a 6 month lifespan equals a factor of 0.5. The inclusion of young animals leads to livestock populations being considerable higher for some categories than the ones published by the IFVA (http://gagnatorg.capacent.is/data/set/1i1j/bufjartolur-1981-2011#!display=line). For the complete methodology of calculating the AAP please refer to Iceland´s National Inventory Report on Greenhouse Gas Emissions (EA, 2012).

Table 6.1 shows the AAP of Icelandic livestock categories for selected years since 1990. The most prominent trends in the development of livestock populations since 1990 are a decrease in dairy cattle and sheep population and an increase in swine and poultry population.

Table 6.1. Annual average population of livestock according to NFR categorization in Iceland for 1990, 1995, 2000, 2005, 2010, and 2011.

	1990	1995	2000	2005	2010	2011
4 B 1 a Cattle dairy	32,249	30,428	27,066	24,538	25,711	25,661
4 B 1 b Cattle non-dairy	42,654	42,771	45,069	41,441	48,070	47,112
4 B 2 Buffalo	NO	NO	NO	NO	NO	NO
4 B 3 Sheep	861,815	719,530	729,290	711,327	748,002	741,466
4 B 4 Goats	504	511	608	641	1,065	1,195
4 B 6 Horses	73,867	80,246	75,630	76,629	78,849	79,943
4 B 7 Mules and asses	NO	NO	NO	NO	NO	NO
4 B 8 Swine	29,645	31,130	32,267	38,438	40,515	43,728
4 B 9 a Laying hens	214,975	164,402	193,097	166,119	174,519	221,167
4 B 9 b Broilers	454,305	188,812	338,756	595,171	537,933	568,560
4 B 9 c Turkeys	0	3,044	10,908	8,120	10,496	10,865
4 B 9 d Other poultry	5,277	5,270	2,498	1,716	1,346	1,343
4 B 13 Other (fur animals)	49,592	37,893	41,431	36,948	37,627	42,057

6.1.3 6.1.3 Emission factors and associated parameters

NH_3 and NO Tier 2 emissions depend on the total amounts of N and TAN in manure. Total N is calculated by multiplying livestock AAP with the nitrogen excretion rate per animal. TAN is calculated by multiplying total N with livestock specific TAN fractions provided by EMEP. The nitrogen excretion rate per livestock category is calculated using default values from p. 10.58 of vol. 4-2 of the 2006 IPCC guidelines (IPCC, 2006) that take animal weight and therefore the smaller size of Icelandic breeds into account. The NEX for dairy cattle is country specific

(Ketilsdóttir and Sveinsson, 2010). Total N and TAN have to be allocated to either slurry or solid manure management. Fractions for slurry and solid manure management are country specific and identical to the ones used in Iceland´s National Inventory Report (EA, 2012). The same is valid for the fractions of the year spent inside. Two more parameters used in the calculation of TAN mass flow are the amount of hay used in animal housing and the amount of N contained in it (only for solid manure management). These amounts (for sheep, goats, and horses) are based on EMEP default data of hay used per day adjusted for the time periods animals stay inside. The above mentioned parameters are summarized in Table 6.2 All manure is assumed to be stored before spreading. Emission factors for animal manure either managed as slurry or solid manure during housing, storage, spreading, and grazing are given as shares of TAN by livestock category in the EMEP GB (pp. 26-27). In absence of default values for sheep slurry, EMEP BG default values for cattle were used instead.

Table 6.2. Parameters used in calculation of NH_3 and NO emissions of manure management.

Livestock category (NFR)	Mean Nex (kg head^{-1} yr^{-1})	Prop. TAN (of N)	Fraction slurry	Fraction solid	Housing period (days)	Straw (kg/yr)	N in straw (kg head^{-1} yr^{-1})
4 B 1 a Cattle dairy	89.1 (72-95)[1]	0.6	1	0	270		
4 B 1 b Cattle non-dairy	31.2 (15-60)[2]	0.6	1	0	29		
4 B 3 Sheep	14.3 (6-29)[3]	0.5	0.33	0.67	200	133	0.53
4 B 4 Goats	20.3	0.5	0	0	201	134	0.54
4 B 6 Horses	28.0 (6-36)[4]	0.6	0	0	51	140	0.58
4 B 8 Fattening pigs	7.6	0.7	1	0	365		
4 B 8 Sows	23	0.7	1	0	365		
4 B 9 a Laying hens	1.4	0.7	0	1	365		
4 B 9 b Broilers	0.8	0.7	0	1	365		
4 B 9 c Turkeys	1.4	0.7	0	1	365		
4 B 9 d Other poultry	1.2	0.7	0	1	365		
4 B 13 Other (fur animals)	5.8 (5-12)[5]	0.6	0	1	365		

[1] Range for time period due to increase in milk production; [2] Range given for subcategories (cows and steers used for producing meat, heifers, and young cattle); [3] Range given for subcategories (ewes, rams, animals for replacement, and lambs); [4] Range given for subcategories (mature horses, young horses, and foals); [5] Range given for subcategories (foxes, minks, and rabbits)

Tier 2 calculations of particulate matter emissions are based on information on the amount of time livestock spends in housing and the fractions of manure either managed as slurry or as solid manure (see Table 6.2 above). The majority of laying hens in Iceland is kept in cages.

6.1.4 Emissions

NH_3 emissions exclude emissions from manure deposited on fields by grazing animals, which are reported under agricultural soils. Total ammonia emissions have been decreasing gently

during the last two decades, from 4.57 Gg in 1990 to 4.37 Gg in 2011. This decrease is mainly due to a decrease of the sheep population. Sheep account for almost 50% of total NH_3 emissions and cattle for approximately 40%. Around 1/3 of emissions occur during livestock housing, 1/4 during manure storage and 2/5 after spreading of manure. The described trends and fractions can be seen in Fig. 6.1.

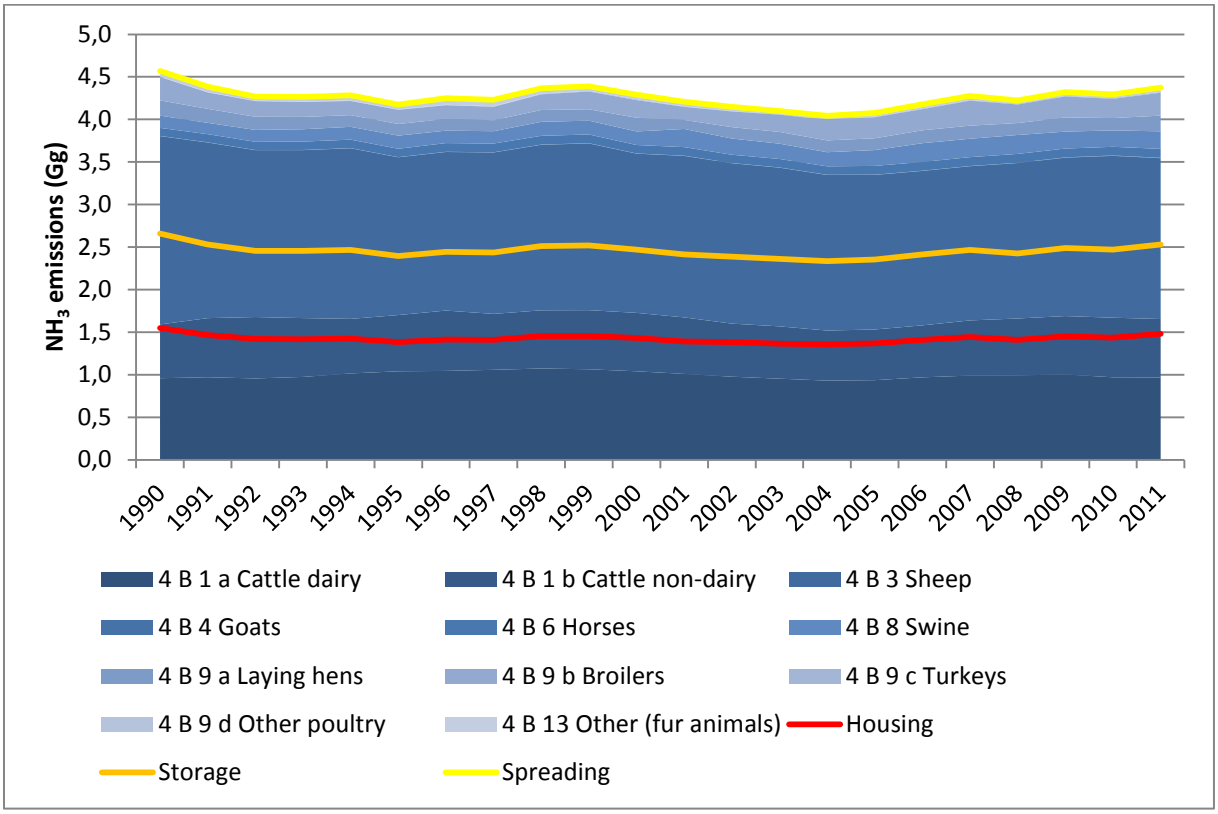

Figure 6.1. Ammonia emissions from animal husbandry and manure management in Gg.

Nitric oxide emissions, in contrast to ammonia emissions, occur only during storage. They have been decreasing from 58 tonnes in 1990 to 52 tonnes in 2011, or by roughly 12%. This decrease is mainly due to the decrease in sheep population already mentioned above. NO emissions from sheep constitute roughly 2/3 of total NO emissions from livestock. NO emissions from poultry amount to 20% of total NO emissions. Other livestock categories with considerable shares are fur animals and horses. Cattle and swine emissions, due to the fact that their manure is stored as slurry, constitute negligible amounts.

PM_{10} emissions increased between from 72 tonnes in 1990 to 81 tonnes in 2011 (12%). Emissions were highest in 2007 when they amounted to 90 tonnes. Both the general increasing trend since 1990 and the decrease since 2007 are almost exclusively due to oscillations in the broiler population, which quintupled between 1996 and 2007. Other livestock categories that emit substantial shares of total PM_{10} emissions from animal husbandry besides broilers, which emitted on average 30% of total PM_{10} emissions between 1990 and 2011, are dairy cattle, cattle, and sheep (each around 20%).

Total $PM_{2.5}$ emissions oscillated between 23 and 27 tonnes from 1990 to 2010 and showed no clear trend. Emissions from cattle constituted more than 70% of total emissions, emissions from swine and broilers each amount to 10% of total emissions.

6.2 Crop production and agricultural soils (4.D)

6.2.1 Methodology

Methodology is based on chapter 4.D of the EMEP/EEA air pollutant emission inventory guidebook (EEA, 2009). Equations and parameters will generally not be listed in this chapter. Instead it is referred to the respective locations in chapter 4.D of the EMEP GB.

Ammonia and particulate matter emissions are calculated with Tier 2 methodology. In absence of higher tiers, nitric oxide and NMVOC emissions are estimated with Tier 1. NH_3 emissions from grazing animals are reported here. Activity data and methodologies used in calculating these emissions have been reported in chapter 6.1 and will not be repeated here. In reporting total NH_3 emissions from crop production and agricultural soils emissions from grazing animals are added to those from fertilizer application.

6.2.2 Activity data

Activity data for NH_3, NO and NMVOC emissions consists of the amount of fertilizer nitrogen applied to agricultural soils. For NH_3 this amount is divided into type of fertilizer N. The total amount of N in fertilizer is provided in the annual reports of the IFVA (http://mast.is/matvaelastofnun/utgafa/skyrslur/#arsskyrslur). There exists no exact data regarding types of N fertilizer. However, it is known that

- N in fertilizer applied in Iceland is mainly contained in calcium ammonium nitrate,
- that the two other fertilizer types of importance are ammonium nitrate and other NK,
- and that less than one per cent of nitrogen is contained in urea (Bjarnason, written communication)

Calcium ammonium nitrate, ammonium nitrate and other NK have identical EF. Therefore their share of total fertilizer was set to 99%. Urea has a considerably higher EF. Its share was set to one per cent.

Activity data for particulate matter emissions consists of the areas of crops cultivated. The total amount of cropland is recorded in the Icelandic geographic land use database (IGLUD), which is maintained by the Agricultural University of Iceland. Data regarding the area of barley fields comes from the Farmers Association of Iceland (http://bondi.lbhi.is/lisalib/getfile.aspx?itemid=2211 and Bragason, written communication). The area of grass fields is calculated by subtracting the area of barley fields from the total cropland area. Barley fields are cultivated and harvested once a year and the produce is cleaned and dried. Grass fields are cultivated about once every 10 years and hay is cut twice per year on average (Brynjólfsson, written communication). Activity data for all reported emissions is summarized in Fig 6.2.

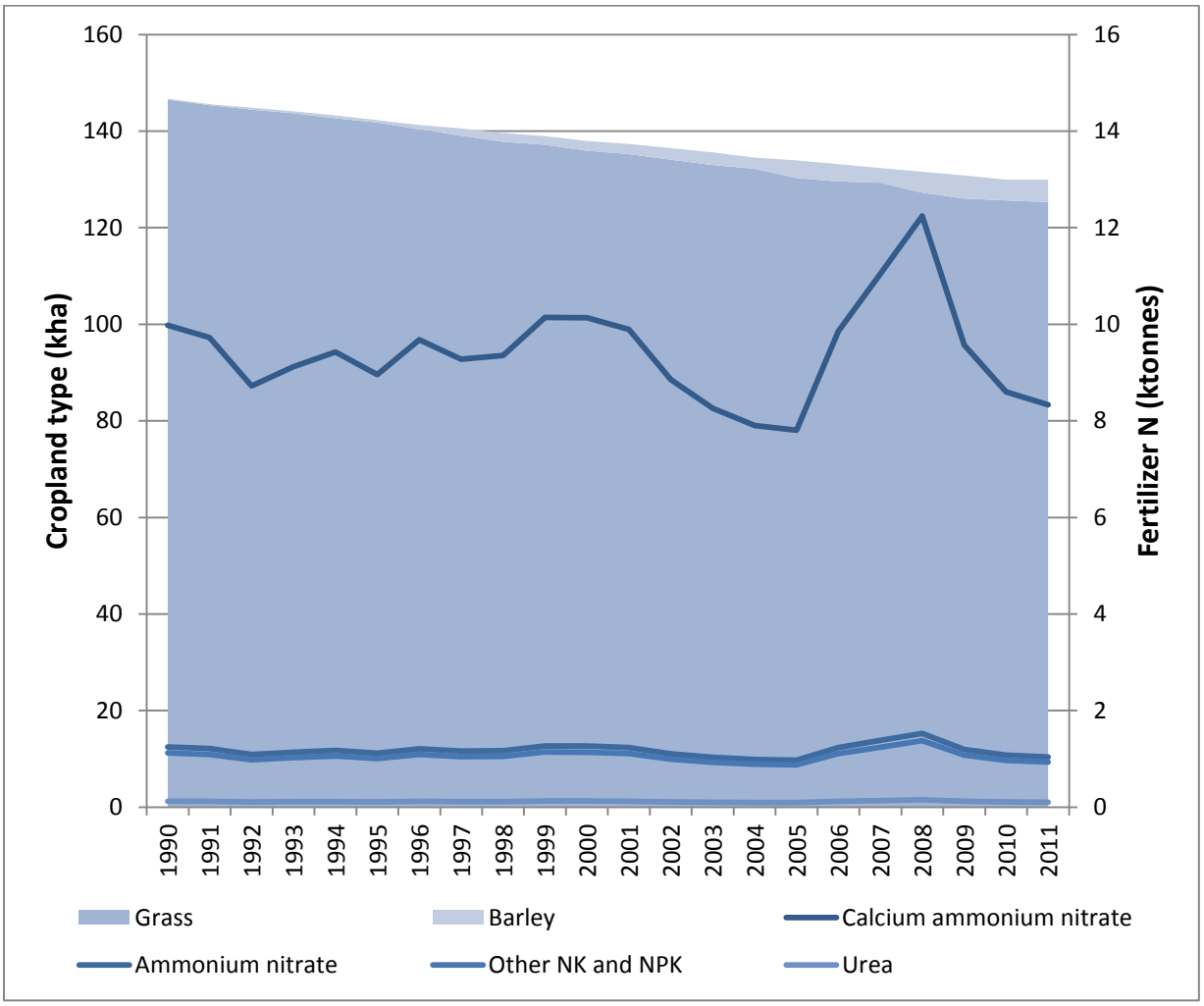

Figure 6.2. Activity data summary for crop production and agricultural soils

6.2.3 Emission factors

NH_3 mission factors were taken from Table 3-2 in the EMEP guidebook (p.14). These emission factors depend on the mean spring air temperature, i.e. the mean temperature of the three month period following the day when accumulated day degrees since January 1st have reached 400 °C. According to this definition the mean spring temperature in Iceland is about 9 °C.

NO and NMVOC emission factors were taken from Table 3-1 of the EMEP GB (p.11) and were 0.026 and 5.96E-09 kg/kg fertilizer applied, respectively.

PM_{10} and $PM_{2.5}$ emission factors for barley and grass were taken from Tables 3-3 and 3-5 of the EMEP GB, respectively (pp. 14-15).

6.2.4 Emissions

Total NH_3 emissions oscillated between 0.9 and 1 Gg between 1990 and 2011. 89% of emissions originate from manure deposited by livestock during grazing and 11% originate

from N fertilizer applied to agricultural soils. Total emissions do not show any discernible trend: while the size of (and thus emissions from) the sheep population is decreasing, is the horse population increasing. N fertilizer application was highest in 2008 but a weakening of the Icelandic currency has made the import of fertilizer more expensive and thusly lead to diminishing application.

The emission development of NO and NMVOC are linearly dependent from the application of fertilizer and therefore show the same development with a peak in 2008 and a 47% decline since then. In 2011 NO emissions amounted to 0.415 Gg and NMVOC emissions from crop production and agricultural soils were 62 grams.

PM_{10} emissions decreased due to the decrease in total cropland from 0.097 Gg in 1990 to 0.089 Gg in 2011. $PM_{2.5}$ emissions on the other hand are estimated to be increasing slightly due to the strong increase in barley cultivation.

6.3 Field burning of agricultural wastes (4.G)

Not reported

6.4 Agriculture other – Use of pesticides and limestone (4.G)

The POP-protocol focuses on a list of 16 substances, 11 of which are pesticides. A number of pesticides, however, had already been banned in Iceland in 1996 in order to conform to EU legislation (Iceland is part of the European Economic Area). The only pesticide of the ones listed in chapter 4.G of the EMEP GB not banned until 2009 is lindane. The last recorded sale of lindane took place in 1992 when 1 kg was sold. In 1990 and 1991 2 and 16.2 kg were sold, respectively. It is assumed that the lindane sold was applied during the same year. An EF of 0.5 as listed in Table 3-1 of the chapter 4.G of the EMEP GB (p. 5) was applied to these values resulting in HCH emissions of 1, 8.1, and 0.5 kg for the years 1990-1992. Table 6.3 gives an overview of the use of pesticides in Iceland.

Table 6.3. Pesticide use and regulation in Iceland.

Pesticide	Last recorded use	Year of ban
Aldrin	1975	1996
Chlordane	No recorded use	1996
DDT	1975	1996
Dieldrin	No recorded use	1996
Endrin	No recorded use	1996
Heptachlor	1975	1996
Hexachlorobenzene (HCB)	No recorded use	1996
Mirex	No recorded use	1998
Toxaphene	No recorded use	1998
Pentachlorophenol (PCP)	No recorded use	1998
Lindane	1992	2009

7 Waste

For most of the 20th century solid waste disposal sites (SWDS) in Iceland were numerous, small and located close to the locations of waste generation so that the waste did not have to be transported far for disposal. In 1967 the waste disposal site in Gufunes was set into operation and most of the waste of the capital´s population landfilled there. Prior to that year, the waste of the capital area was landfilled in smaller SWDS.

Until the 1970s the most common form of waste management outside the capital area was open burning of waste. In some communities waste burning was complemented with landfills for bulky waste and ash. The existing landfill sites did not have to meet specific requirements regarding location, management and aftercare before 1990 and were often just holes in the ground. Some communities also disposed of their waste by dumping it into the sea. Akureyri and Selfoss, two of the biggest communities outside the capital area opened municipal SWDS in the 1970s and 1980s.

Before 1990 three waste incinerators were opened in Keflavík, Húsavík and Ísafjörður. Totalled up they burned around 15,000 tonnes of waste annually. They operated at low or varying temperatures and the energy produced was not utilised. Waste incineration in Iceland as such started in 1993 with the opening of the incineration plant in Vestmannaeyjar, an archipelago to the south of Iceland. At the start of 2011 a total of five waste incineration plants were in use. Some of them recover energy and use it for either public or commercial heat production. Open burning of waste was banned in 1999. The last place to burn waste openly was the island of Grímsey which stopped doing so by end of 2010.

Recycling and biological treatment of waste started on a larger scale in the beginning of the 1990s. Their share of total waste management increased rapidly since then.

Reliable data about waste composition does not exist until recent years. In 1991 the waste management company Sorpa ltd. started serving the capital area and has gathered data about waste composition of landfilled waste since 1999. For the last few years the waste sector has had to report data about amounts and kinds of waste landfilled, incinerated, and recycled.

The special treatment of hazardous waste did not start until the 1990s, i.e. hazardous waste was landfilled or burned like non-hazardous waste. Special treatment started with the reusing of waste as energy source. In 1996 the Hazardous waste committee (*Spilliefnanefnd*) was founded and started a collection scheme for hazardous waste. The collection scheme included fees on hazardous substances that were refunded if the substances were delivered to hazardous waste collection points. Hazardous substances collected included oil products, organic solvents, halogenated compounds, isocyanates, oil-based paints, printer ink, batteries, car batteries, preservatives, refrigerants, and more. After collection, these substances were destroyed, recycled or exported for further treatment. The Hazardous waste committee was succeeded by the Icelandic recycling fund in late 2002. In 2011, 599

tonnes of hazardous waste were landfilled, 714 tonnes were incinerated, 6267 tonnes were recycled, and 42 tonnes of acid were neutralized.

Clinical waste has been incinerated in incinerators either at hospitals or at waste incineration plants. 275 tonnes of clinical waste were incinerated in 2011.

The trend in waste management practices has been toward managed SWDS as municipalities have increasingly cooperated with each other on running waste collection schemes and operating joint landfill sites. This can be seen in Figure 7.1 and Figure 7.2, which show different waste management practices in 1990 and 2010. This has resulted in larger SWDS and enabled the shutdown of a number of small sites. In 2011, more than 80% of all landfilled waste was disposed of in managed SWDS. Recycling of waste has increased due to efforts made by the government, local municipalities, recovery companies, and others. Composting started in the mid-1990s and has increased since then.

In 2011, about 35% of all waste generated was landfilled, 57% recycled or recovered, 5% incinerated, and 3% composted.

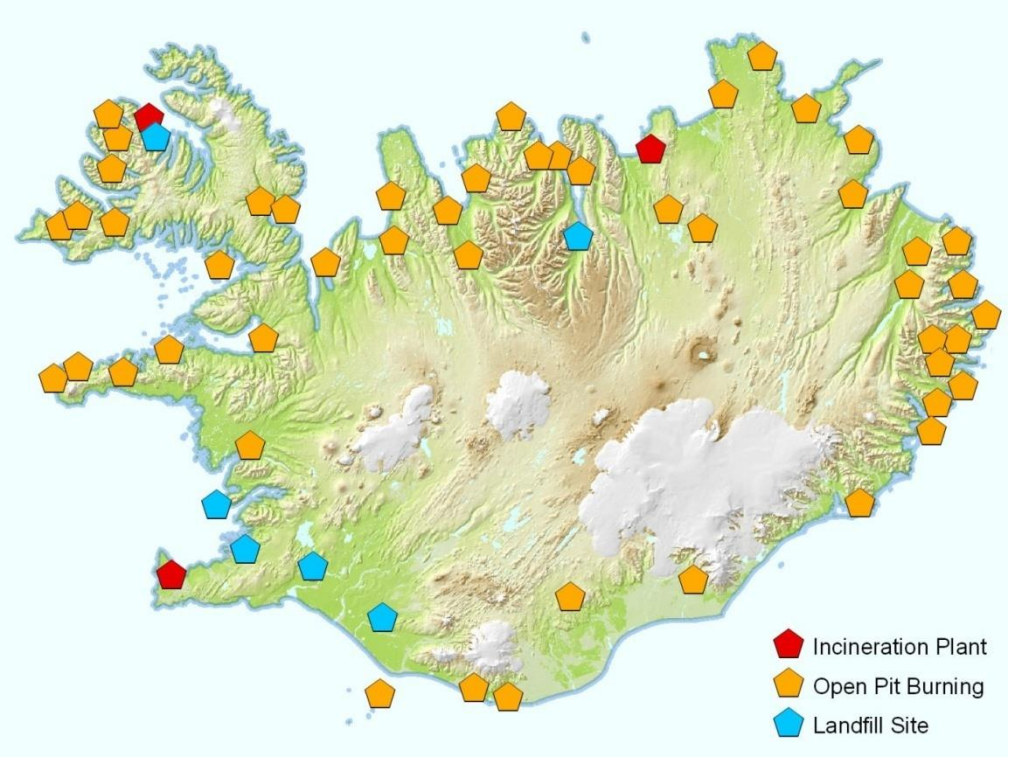

Figure 7.1. Waste management practices in 1990

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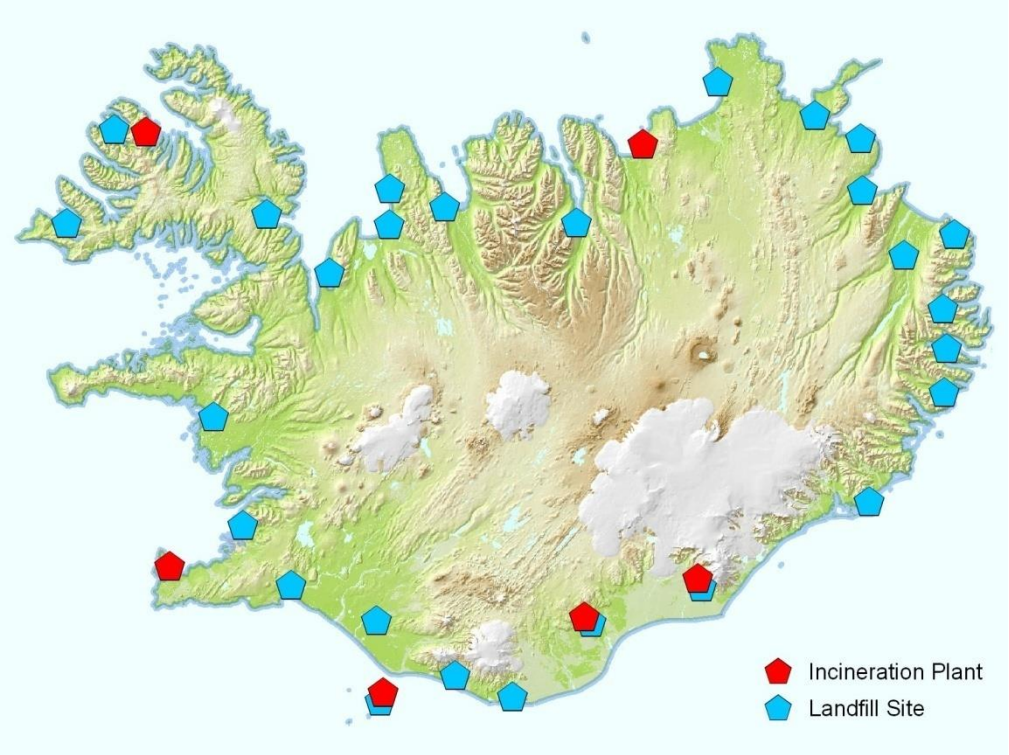

Figure 7.2. Waste management practices in 2010. In 2010 two inceration plants (Svínafell in south Iceland and Ísafjörður in the Westfjords, as well as the open pit burning at Grimsey, an island north of Iceland, were closed down).

7.1 Solid waste disposal on land (6A)

Major emissions from waste disposal at landfill sites are emissions of greenhouse gases. It is assumed that emissions of small quantities of NMVOC, CO, NH_3 and NO_x occur at landfill sites. PM emissions are emitted from waste handling as well, but no emission factors are available. For this submission emissions of NMVOC were estimated for the first time.

7.1.1 Activity data

Information on the amounts of waste landfilled as well as its composition can be found in Iceland´s National Inventory Report on greenhouse gas emissions. In the greenhouse gas inventory a first order decay model is used to estimate methane emissions from landfills. By setting the methane correction factor to one for all SWDS and by assuming a methane content of 50 volume % the model can be used to estimate the amount of landfill gas emitted which is needed to estimate NMVOC emissions.

7.1.2 Emission factors

NMVOC emissions are calculated using the Tier 1 emission factor supplied by the EMEP guidebook of 5.65 g/m^3 landfill gas (EEA, 2009).

7.1.3 Emissions

NMVOC emissions amounted to 0.2 Gg in 2011 which is a 14% increase from the estimate for 1990. NMVOC emissions show a trend similar to the methane emission trend: increasing

emissions until 2007 caused by an increase in waste generation followed by a decrease in emissions due to decreasing amounts of organic waste landfilled since the early 2000s.

7.2 Waste water handling (6B)

According to the EMEP guidebook (EEA, 200) wastewater will be an insignificant source for air pollutants. However, in urban areas, non-methane volatile organic compounds (NMVOC) emissions from waste water treatment plants can be of local importance. Activities considered within this sector are biological treatment plants and latrines (storage tanks of human excreta, located under naturally ventilated wooden shelters).

In Iceland most wastewater is discharged into the sea either untreated or after primary treatment. Only a small amount of wastewater is treated with secondary treatment and latrines are not occurring. Therefore non-GHG emissions are not estimated from wastewater handling.

7.3 Waste incineration (6C)

This chapter deals with incineration, open burning of waste, bonfires and cremation. Incineration of waste is subdivided into incineration with energy recovery (reported under 1A1a and 1A4) and incineration without energy recovery.

Activity data

Activity data on waste in Iceland has proven to have been insufficient in the past. There is little information about actual amounts of generated waste as well as on its composition and characteristics, before 1990. Activity data on incinerated waste from major incineration plants have been collected by the EA since 2000. Historic data as well as data on open pit burning not reported to EA, was estimated with the assumptions that 500 kg of wastes have been incinerated per inhabitant in the communities where waste is known to have been incinerated (both in primitive incineration plants as well as open pit burning) in 1990, 1995 and 2000 and interpolated in the years between. These communities were mapped by EA in the respective years. The data after the year 2000 is considered rather reliable, but pre-2000 data very unreliable.

In 1993 incineration plants were opened on the Vestmannaeyjar archipelago and in Svínafell in southeast Iceland. These two plants as well as three more, which were opened in 1995 (Ísafjörður), 1999 (Skaftárhreppur), and 2006 (Húsavík) recover the energy of the incineration and use it for either public heat production (Vestmannaeyjar, Ísafjörður, Húsavík) or commercial/institutional heat production (Svínafell, swimming pool; Skaftárhreppur, swimming pool, school building). Svínafell and Ísafjörður stopped operation in late 2010. The incineration plant Kalka (established in 2005) produces energy and electricity for its own requirements and therefore rates as auto producer. Thus it is categorized as incineration plant without energy recovery as is Tálknafjörður, a small incinerator which operated from only from 2001 to 2004. Emissions from waste incineration

with energy recovery are reported in sector 1A1a (public electricity and heat production) and 1A4a (commercial). Amounts of waste incinerated are presented in Table 7.1.

Table 7.1. Waste incineration from 1990 to 2011, thousand tonnes

Year	Incineration with energy recovery (1A1a)	Incineration with energy recovery (1A4)	Incineration plants (6C)	Open pit burning	Bon fires
1990	-	-	-	33.8	4.3
1991	-	-	-	33.5	4.3
1992	-	-	-	32.6	4.3
1993	3.7	0.5	-	27.8	4.2
1994	3.7	0.5	-	25.6	4.0
1995	4.7	0.5	-	22.6	3.9
1996	6.1	0.5	-	20.2	3.7
1997	6.1	0.5	-	19.5	3.4
1998	6.1	0.5	-	16.5	3.2
1999	6.1	0.6	-	13.5	3.0
2000	6.1	0.6	-	12.7	3.4
2001	6.1	0.6	0.2	11.6	2.8
2002	6.1	0.6	0.2	10.8	2.7
2003	6.1	0.9	0.2	9.1	2.5
2004	6.2	0.8	9.8	4.3	2.4
2005	6.0	0.5	10.9	0.05	2.3
2006	10.7	0.6	11.4	0.05	2.2
2007	12.0	0.7	13.2	0.05	2.1
2008	10.3	0.4	11.7	0.05	2.0
2009	8.0	0.3	95	0.05	1.9
2010	8.1	0.3	9.3	0.05	1.8
2011	6.4	0.2	9.8	NO	1.7

Emission factors

Emission factors for dioxin for waste incineration are based on measurements at the plants, except for Kalka which reports its emissions. Several point measurements exist in the period 2007 to 2011. Average emission from these measurements at similar incineration plants (Hoval technique) at Ísafjörður, Skaftárhreppur and Vestmannaeyjar was close to 50 µg/t. As all these incineration plants are operated as batch, an emission factor for those plants was chosen to be 100 µg/t. The incineration plant at Ísafjörður was closed down in 2010, after a period of malfunctioning. No dioxin measurements took place at the plant for the last three years of operation. Other pollutants were measured at the plant, indicating that there were significantly more emissions of all pollutants for the last three years of operation. For those years, the emission factor of 300 µg/t for uncontrolled domestic waste burning, was taken

from the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP 2005). This factor is also used for the incineration plant at Svínafell (also Hoval technique), based on measurements at the plant. For the incineration plant at Húsavík an emission factor of 10 µg/t was chosen, based on measurements. Emission factors for PAH, HCB, NO_x, SO_2, CO, and NMVOC are taken from table 3.1 in chapter 6.C.c of the Emission Inventory Guidebook (EEA, 2009). They do not differentiate between different incinerations techniques and are applied to the total waste amount incinerated. The emission factors are presented in Table 7.2.

Table 7.2. Emission factors for dioxin, HCB, PAH, NOx, CO, NMVOC and SO_2 from waste incineration

	dioxin [µg I-TEQ/t]	BaP [mg/t]	BbF [mg/t]	BkF [mg/t]	HCB [mg/t]	NOx [kg/t]	CO [kg/t]	NMVOC [kg/t]	SO_2 [kg/t]
Open pit burning	300	0.7	3.15	3.15	2	1.8	0.7	0.02	0.4
Hoval technique*	100	0.7	3.15	3.15	2	1.8	0.7	0.02	0.4
Húsavík	10	0.7	3.15	3.15	2	1.8	0.7	0.02	0.4
Kalka	Reported	0.7	3.15	3.15	2	1.8	0.7	0.02	0.4

* The incineration plant at Svínafell is classified as open pit burning

Open pit burning

Open burning of waste includes combustion in nature and open dumps as well as combustion in incineration devices that do not control the combustion air to maintain adequate temperature and do not provide sufficient residence time for complete combustion. Incineration devices on the other hand are characterised by creating conditions for complete combustion. Therefore the burning of waste in historic incineration devices that did not ensure conditions for complete combustion is allocated to open burning of waste. As can be seen from Table 7.1 open pit burning was a common procedure in the early nineties. In general open pit burning results in poor combustion conditions due to inhomogeneous and poorly mixed fuel material, chlorinated precursors, humidity or catalytically active metals, but all these factor influence the dioxin formation. It can therefore be hard to come up with a reasonable emission factors. In addition to that the activity data is quite uncertain as well, as no official statistics are available. Historic data on open pit burning was estimated with the assumptions that 500 kg of wastes have been incinerated per inhabitant in the communities where waste is known to have been incinerated in 1990, 1995 and 2000 and interpolated in the years between. These communities were mapped by EA in the respective years. The date is known at the EA, at which sites, where open pit burning has been performed have been closed down and other means of waste disposal have been found. Open pit burning is likely to occur still at various rural sites, but this has not been estimated. The amount of waste burned in open pits has decreased rapidly since the early 1990s, when more than 30 thousand tonnes of waste were burned. Between 2005 and 2010 there was only one site left burning waste openly: the island of Grímsey. This site was closed by the end of 2010. It was assumed that around 50 tonnes of waste were burned there annually.

Emission factor for dioxin for open pit burning are taken from table 54 in the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP 2005), it is 300 µg per tonne waste (given for uncontrolled domestic waste burning). Emission factors

for PAH4, HCB, NOx, CO, NMVOC and SO_2 are taken from table 3.1 in chapter 6.C.c of the Emission Inventory Guidebook (EEA, 2009). They are presented in Table 7.2 above.

Bonfires

It is a tradition to light up bonfires at New Year's Eve in Iceland. These are quite common throughout the country. In the early nineties there were no restrictions and no supervision with these bonfires. In the early nineties some surveillance officers from the Environmental and Public Health Offices (Local Competent Authority) started to control these fires, by informing the bonfire personnel. In 2000 the EA, Iceland Fire Authority and National Commissioner of Iceland Police published guidelines for bonfires. They include restrictions on size, burnout time and the material allowed. Since that time only wood and paper are allowed on bonfires. Also the Environmental and Public Health Offices supervise all bonfires. Now they are fewer and better organized.

Activity data is not easily obtained. In 2011 the EA along with the municipality of Reykjavík decided to weigh all the material of a single bonfire. Then the piled material was photographed and height, width and length measured. The weight was then correlated to the more readily measureable parameters pile height and diameter. The Environmental and Public Health Offices were asked to measure height and diameter of the bonfires in their area, take pictures and send to EA. From this information the total weight of bonfires was estimated for the whole country. The amount was further extrapolated back to 1990, in cooperation with an expert from one Environmental and Public Health Office that has been involved with this field of work for a long time.

Emission factor are also difficult to estimate. From 2003 onwards an emission factor of 60 µg/t is used. This factor is taken from table 54 of the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP 2005) and is given for open burning of wood. For 1990 to 1995 an emission factor of 600 µg per tonne burnt material was used. This relates to the fact that the burning material was very miscellaneous at that time. It was common practice to burn tires, kitchen interior and even boats at the bonfires. Further some businesses used the opportunity to get rid of all kind of wastes. Therefore it was considered suitable to double the emission factor used for open pit burning. The emission factor was then interpolated from 600 µg to 60 µg per tonne burned material from 1996 to 2003. The emission factors for other pollutants than dioxin are the same as for waste incineration, as presented in Table 7.2 above.

Cremation

Cremation is performed at a single facility, located in Reykjavík. Human bodies are incinerated along with the coffin. The heat at the combustion chamber reaches high temperatures. Emissions of dioxins and PAH (emission factor is only given for BaP) are estimated. Activity data was collected from the single facility. Emission factors are 0.0168 µg/body for dioxin and 0.0103 µg/body for BaP. They are taken from the Emission Inventory Guidebook (EEA, 2009).

7.4 Other waste

This section deals with emissions from compost production and accidental vehicle and building fires. Emissions from landfill fires have not been estimated.

7.4.1 Compost production

Compost production in Iceland started in 1995 and has increased annually since then. In 2011 more than 14,000 tonnes of waste were composted. NH_3 emissions from waste composting were calculated by multiplication of waste amounts with a default emission factor of 0.24 kg/Mg organic waste (EEA, 2009).

7.4.2 Vehicle and building fires

Activity data for vehicle and building fires were obtained for the years 2003 to 2012 from the Capital District Fire and Rescue Service (CDFRS). Building fires are classified by duration of response into small, medium and large fires. The data is presented in Table 7.23. As 2/3 of the Icelandic population lives in the capital area, it is assumed that the CDFRS serves 2/3 of the incidents in Iceland. In Table 7.24., data on vehicle and building fires, extrapolated for Iceland, is presented. As the emission factors used comply for full scale building fires, the activity data is scaled as a full scale equivalent where it is assumed that a medium and a small fire leads to 50% and 5% of a large fire respectively, and that a large fire is a full scale fire. Table 7.24. shows the total scaled building fires. This scaling is similar to the scaling used in the 2011 Danish Informative Inventory Report, although the scaling in Denmark is based on response activity rather than response time. It does though seem appropriate to scale the fires in this way for the Icelandic data. It is further assumed that 10% of the building fires every year, are industrial building fires. In 2004 a major industrial fire broke out at a recycling company (Hringrás). In the fire 300 tonnes of tires, among other separated waste materials, burned. In 2011 a fire broke out at the same company, but that fire is assumed to have been about 10% of the size of the one in 2004.

Table 7.3. Vehicle and building fires, capital area.

	Vehicle fires, capital area	Buiding fires, capital area		
		<=59 min	60-119 min	>=120 min
2003	36	161	21	4
2004	25	153	24	5
2005	43	141	24	11
2006	34	130	24	9
2007	44	142	20	7
2008	64	150	25	9
2009	46	114	16	12
2010	34	118	17	9
2011	35	121	10	5
2012	36	99	24	9

Table 7.4. Vehicle and building fires, Iceland

	Vehicle fires, Iceland	Building fires, Iceland			Total scaled building fires
		<=59 min	60-119 min	>=120 mn	
2003	54	242	32	6	34
2004	38	230	36	8	38
2005	65	212	36	17	46
2006	51	195	36	14	42
2007	66	213	30	11	37
2008	96	225	38	14	44
2009	69	171	24	18	39
2010	51	177	26	14	36
2011	53	182	15	8	25
2012	54	149	36	14	39

For the year 1990 to 2002 an average of the total scaled building fires (38) and the vehicle fires (60) was used.

Emissions from vehicle fires are calculated by multiplying the number of vehicle fires with selected emission factors. Emission factors are not available for different vehicle types, whereas it is assumed that all the different vehicle types leads to similar emissions. The activity data is calculated as a yearly combusted mass by multiplying the number of different vehicles fires with the average weight of the given vehicle type. As it is not registered at the CDRFS which types of vehicles are caught in fires, the average Danish (2011 Danish Informative Inventory Report) ratio of vehicle fires per vehicle type were taken per vehicle type, excluding motorcycles, as motorcycle fires are very rare in Iceland (passenger cars 83%; buses 8%; light duty vehicles 3%; heavy duty vehicles 7%). The total amount of vehicle mass involved in fires is then calculated from the number of vehicle fires and the average weights of the different vehicle types (also Danish weight, as information was not available). It is assumed that 70% of the total vehicle mass involved in a fire actually burns. The burned mass is then multiplied with emission factors for dioxin and PAH4. They are taken from the Annual Danish Informative Inventory Report to the UNECE (National Environmental Research Institute, 2011) and are 0.0428 mg dioxin per fire, 14.7 g BaP per tonne, 32.3 g BbF and BkF per tonne and 23.3 g IPy per tonne.

Emission factors for building fires are also taken from the Annual Danish Informative Inventory Report to the UNECE (National Environmental Research Institute, 2011). Emission factor for undetached houses is used for all building fires except industrial building fires. This is due to the fact that Icelandic regulation demand more fire resistance than the regulations in the Scandinavian countries. The emission factors for undetached and industrial buildings are given inTable 7.25.

Table 7.5.Emission factors, building fires.

	Dioxin [µg/fire]	BaP [g/fire]	BbF [g/fire]	BkF [g/fire]	IPY [g/fire]
Undetached buildings	2.52	6.36	10.1	3.6	6.9
Industrial buildings	7.13	18.0	28.5	10.1	19.5

At the major industrial fire at Hringrás in 2004, 300 tonnes of tires, among other separated waste materials, burned. An emission factor of 300 µg/t of tires from the Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases (UNEP 2005), was taken. Using this factor, this single fire scaled like about 9 industrial building fires. For PAH4 the emission factor for industrial building was used, multiplied by 9.2 to account for this major incident.

8 Other and natural emissions

Iceland reports emissions from volcanos in 2010 as Eyjafjallajökull erupted and in 2011 as Grímsvötn erupted. For the Eyjafjallajökull eruption in 2010 emissions of sulphur dioxide and particulate matter were estimated and reported. The emissions estimates are based on satellite observation on a daily basis during the eruption (https://wiki.met.no/emep/emep_volcano_plume) and amounted to 127 Gg of SO_2, around 6000 Gg of PM10 and around 1700 Gg of PM2.5. The eruption at Grímsvötn was much larger than at Eyjafjallajökull, and it has been estimated that during the first day more sulphur and particulates were emitted than during all the Eyjafjallajökull eruption. SO_2 emissions from Grímsvötn have been estimated to be around 1000 Gg. An estimate of the total particulates emitted has not been estimated but the EA has scaled the emissions of particulates using the ratio of sulphur emissions from the two eruptions (1000/127). This gives an approximate estimate of of around 47,000 Gg PM10 and 13,000 Gg of PM2.5. These emissions are not included in national totals.

Table 8.1 Eruption emission parameters.

	PM10 [kg/s]	PM2.5 [kg/s]	SO2 [kg/s]	height [km]
14.4.2010	1,00E+03	2,80E+02	15	8
15.4.2010	5,00E+03	1,40E+03	46	7
16.4.2010	5,00E+03	1,40E+03	15	7
17.4.2010	9,00E+03	2,50E+03	10	7
18.4.2010	2,00E+03	5,60E+02	10	5
19.4.2010	7,00E+03	2,00E+03	20	5
20.4.2010	3,00E+02	8,40E+01	15	4
2010-04-21—2010-04-29	3,00E+02	8,40E+01	15	3
2010-04-30—2010-05-02	3,00E+02	8,40E+01	15	4
2010-05-03—2010-05-04	2,00E+03	5,60E+02	15	5
5.5.2010	2,00E+03	5,60E+02	70	5
2010-05-06—2010-05-20	2,00E+03	5,60E+02	70	6
21.5.2010	1,00E+02	2,80E+01	5	3
22.5.2010	1,00E+02	2,80E+01	2	3
23.5.2010	0	0	1	2
2010-05-24—today	0	0	0	0

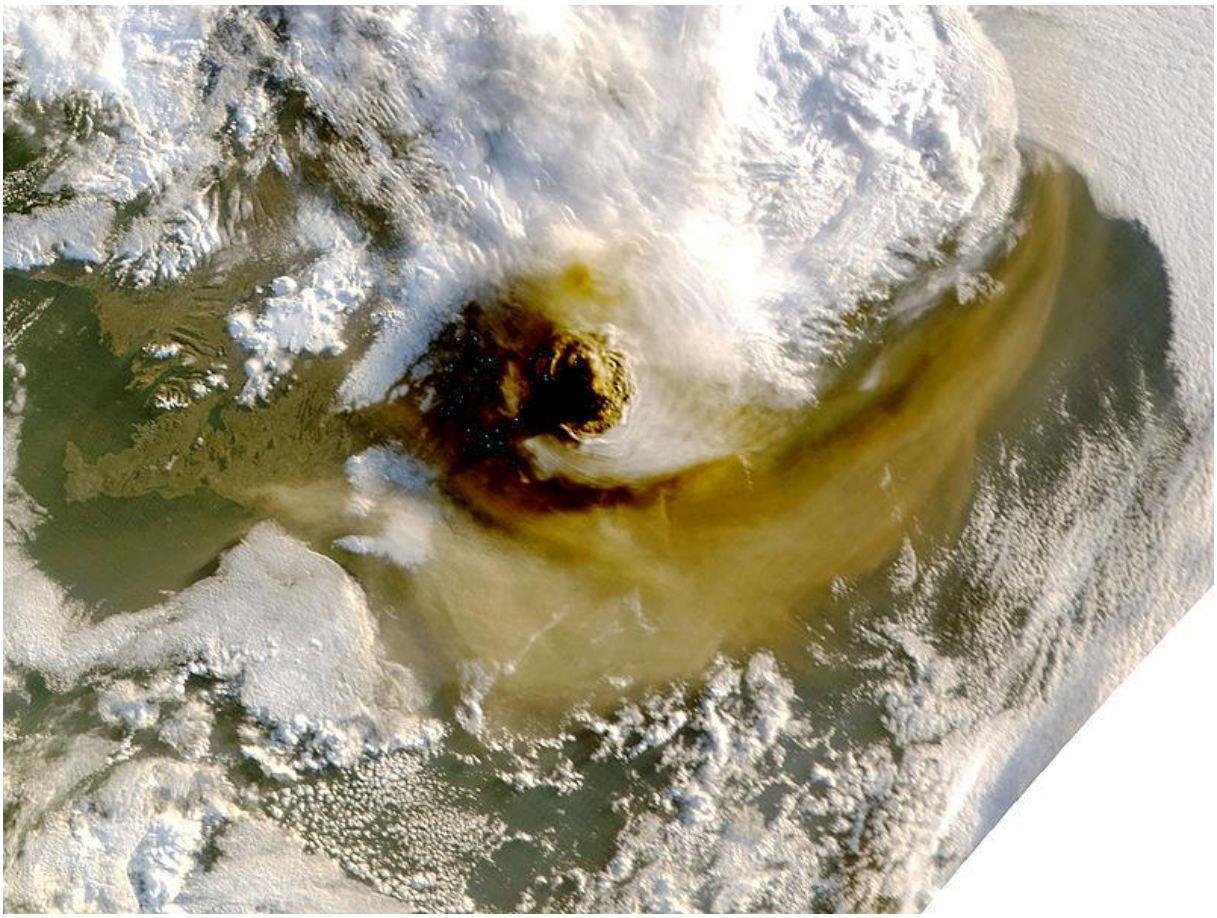

Figure 8.1. Grímsvötn eruption in May 2011.

Figure 8.1, a NASA MODIS satellite image acquired at 05:15 UTC on May 22, 2011 shows the plume from Grímsvötn casting shadow to the west. (Photo NASA/GSFC/Jeff Schmaltz/MODIS Land Rapid Response Team).

9 Spatially distributed emissions on grid

Geographically distributed emissions, are reported for the years 1990, 1995, 2000, 2005 and 2010 for dioxin and PAH4. Emission data have been disaggregated to the standard EMEP grid with a resolution of 50km x 50km. The reported emissions include gridded data for sector totals as well as national totals. Emissions for aviation, navigation and fishing have not been gridded.

When gridding the data all industrial sources and waste incineration sites (open pit burning and incineration plants) have been mapped with coordinates and projected on the grid. Other emissions like emissions from road transport, accidental fires, and bon fires have been divided on the grid based on population data. Some minor sources like emissions from tobacco smoking have been located where the populations density is highest, i.e. the capital area.

Figures 9.1 to 9.5 show national total emissions of PAH4 within the EMEP-Grid in 1990, 1995, 2000, 2005 and 2010.

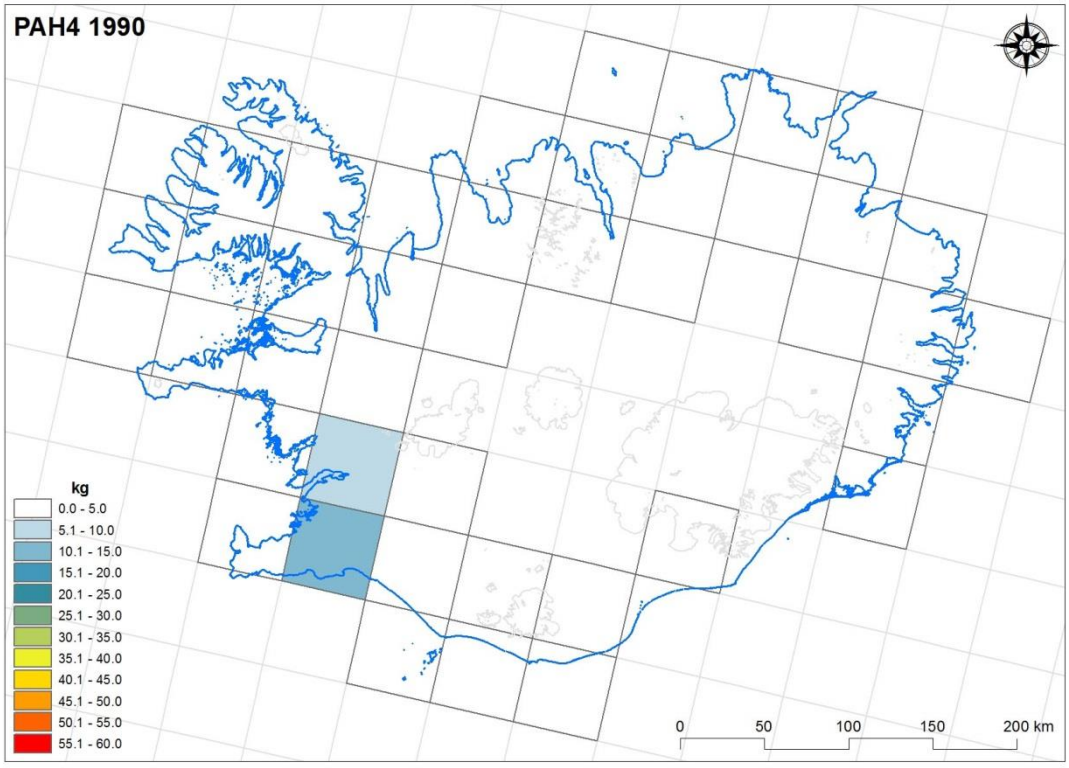

Figure 9.1. Emissions of PAH4 within the EMEP-Grid in 1990.

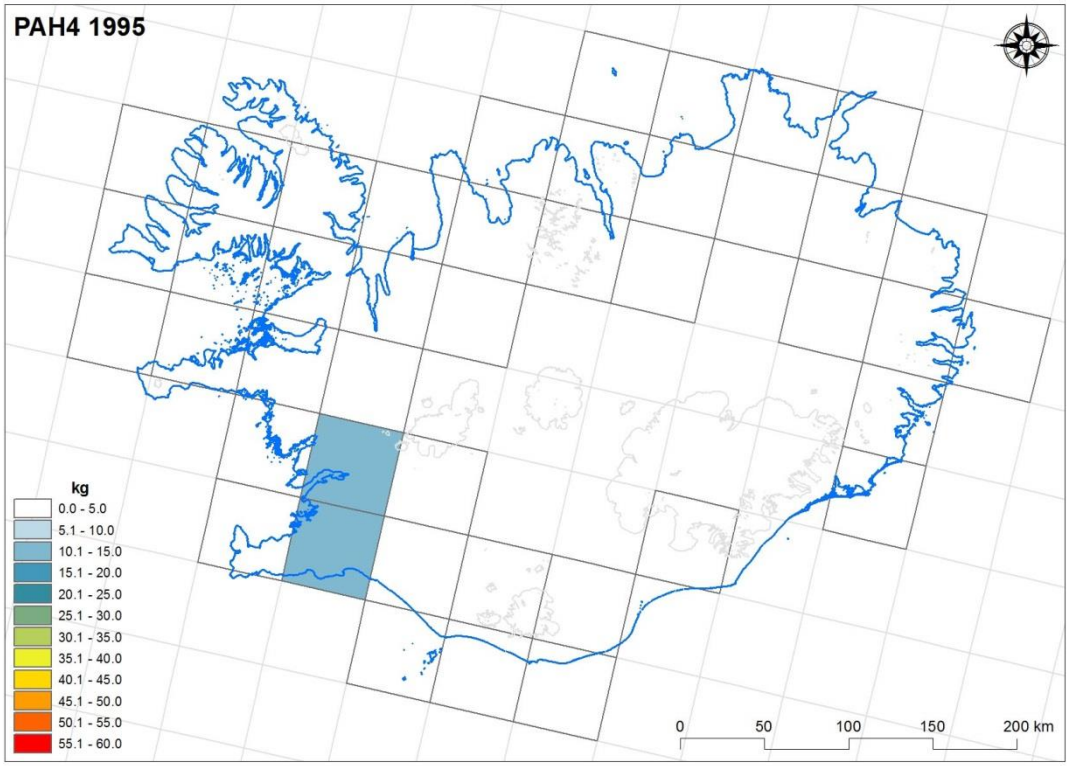

Figure 9.2 Emissions of PAH4 within the EMEP-Grid in 1995.

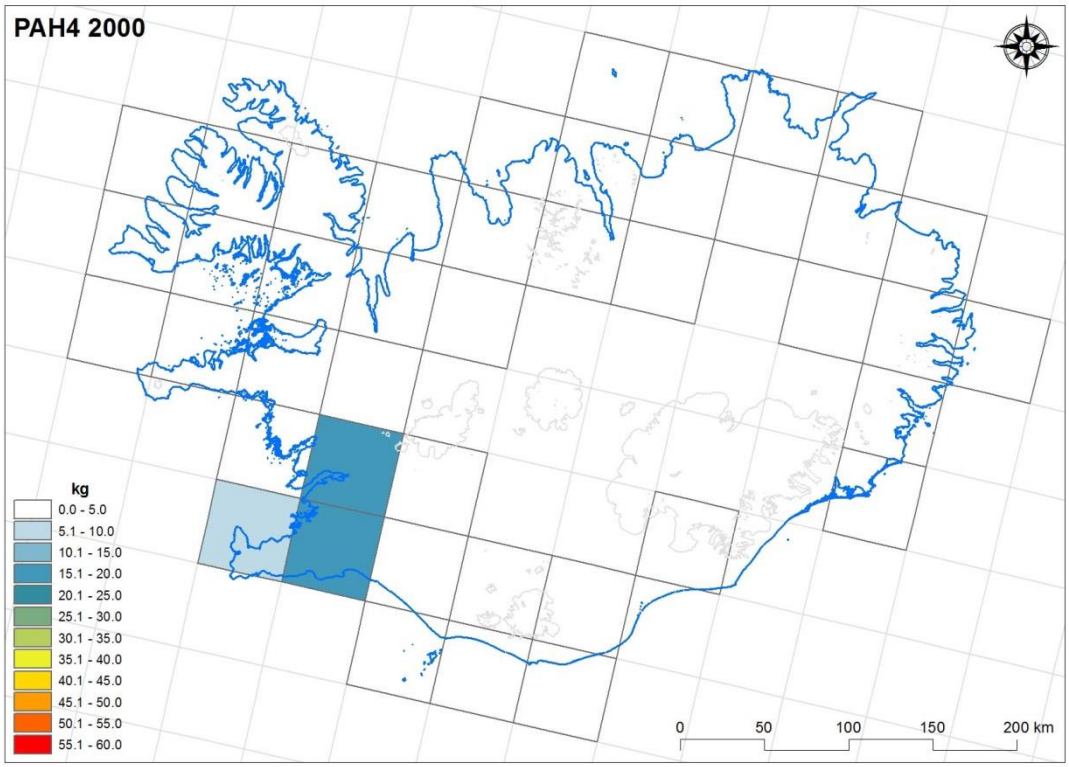

Figure 9.3. Emissions of PAH4 within the EMEP-Grid in 2000.

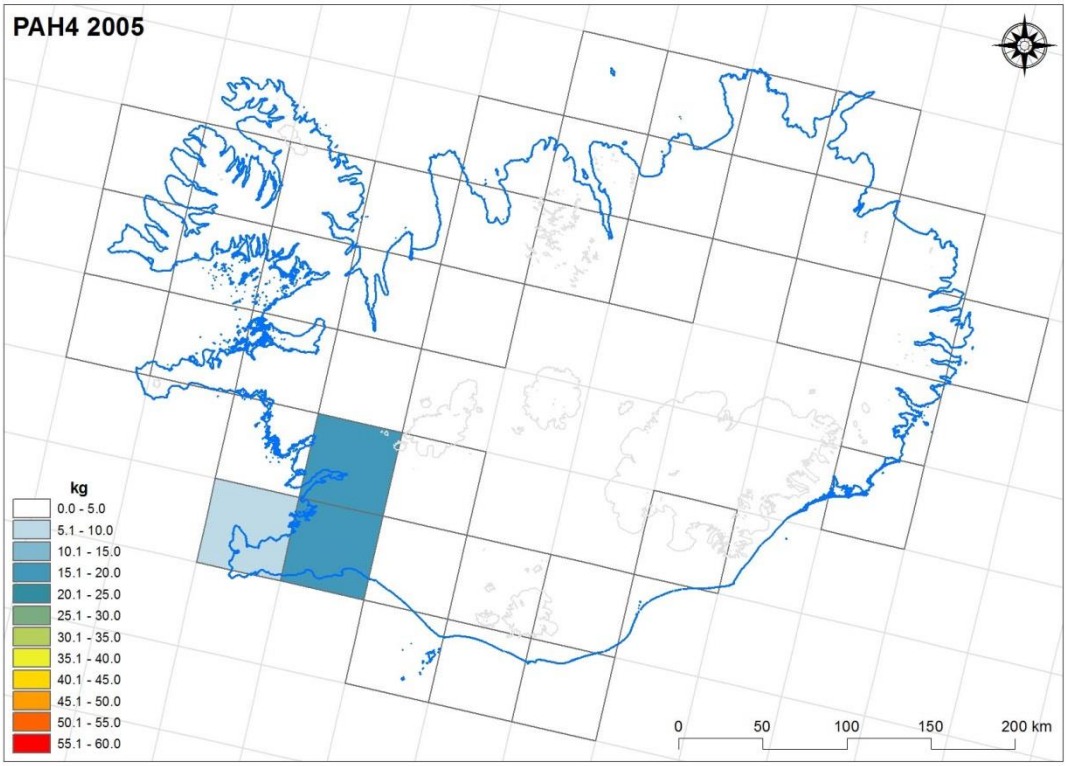

Figure 9.4. Emissions of PAH4 within the EMEP-Grid in 2005.

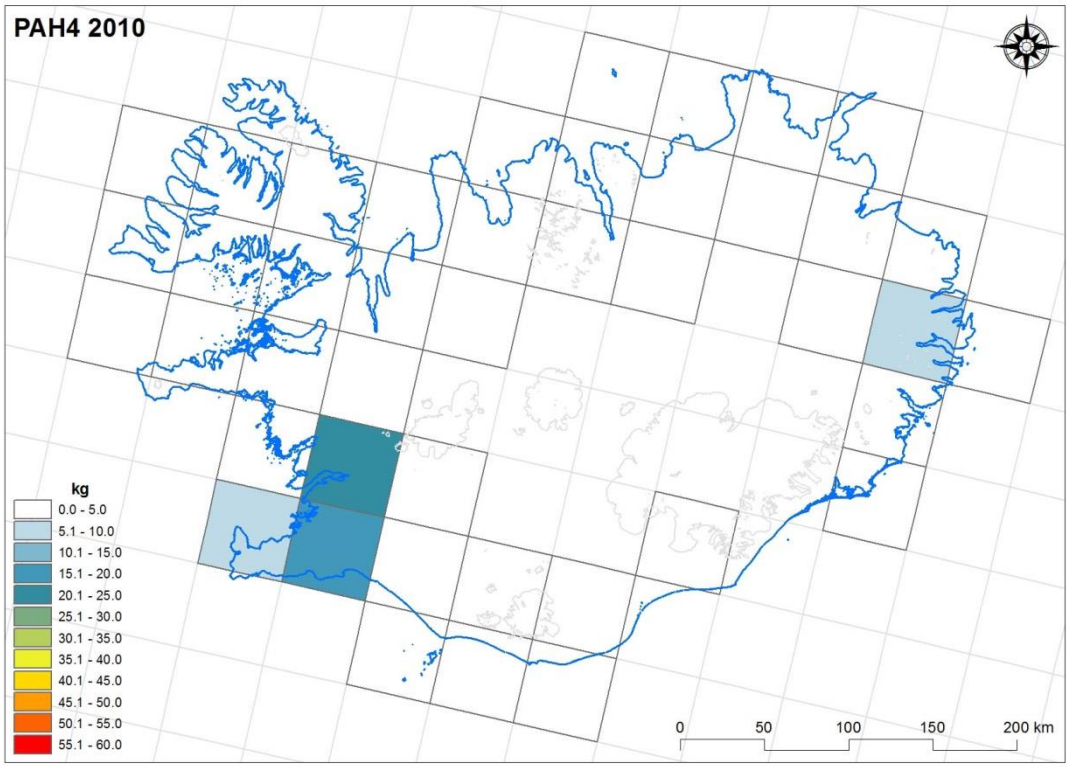

Figure 9.5. Emissions of PAH4 within the EMEP-Grid in 2010.

Figures 9.6 to 9.10 show the national total emissions of dioxin within the EMEP-Grid in 1990, 1995, 2000, 2005 and 2010.

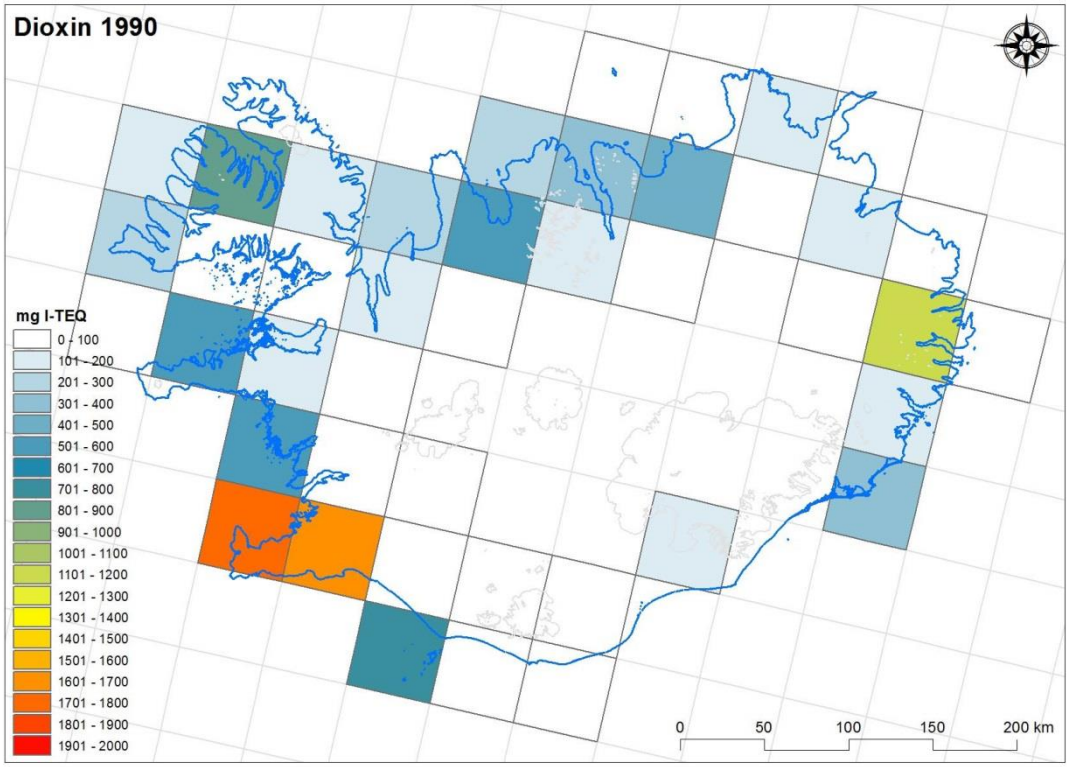

Figure 9.6. Emissions of dioxins within the EMEP-Grid in 1990.

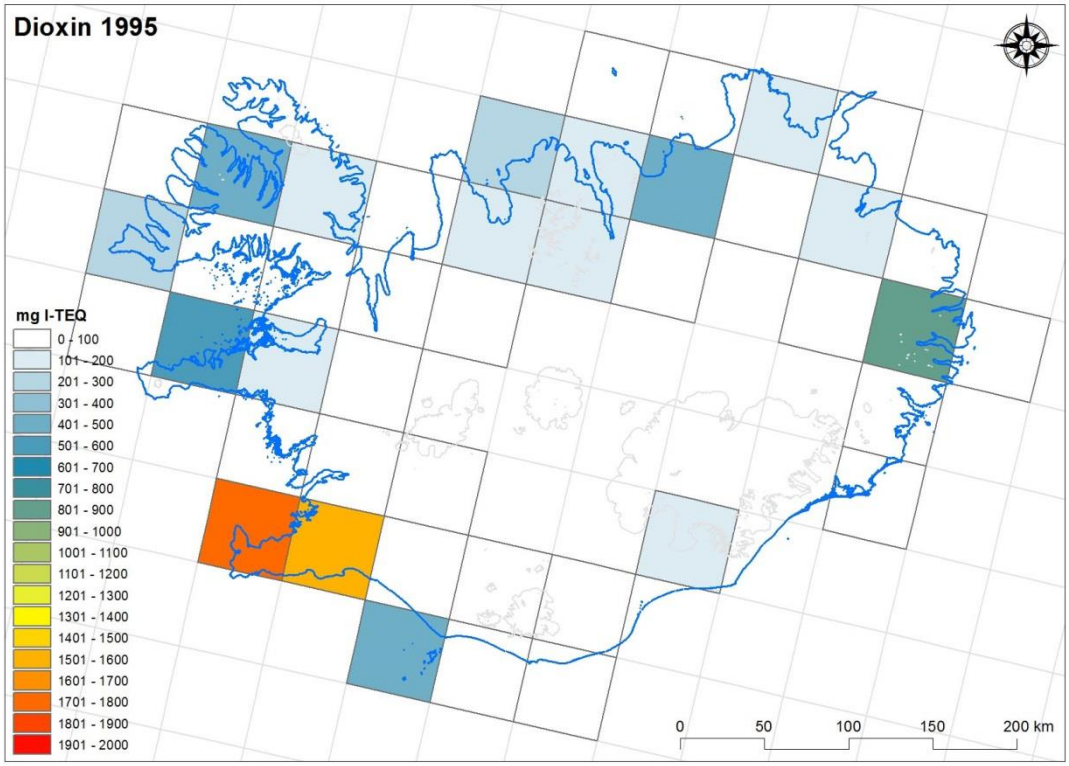

Figure 9.7. Emissions of dioxins within the EMEP-Grid in 1995.

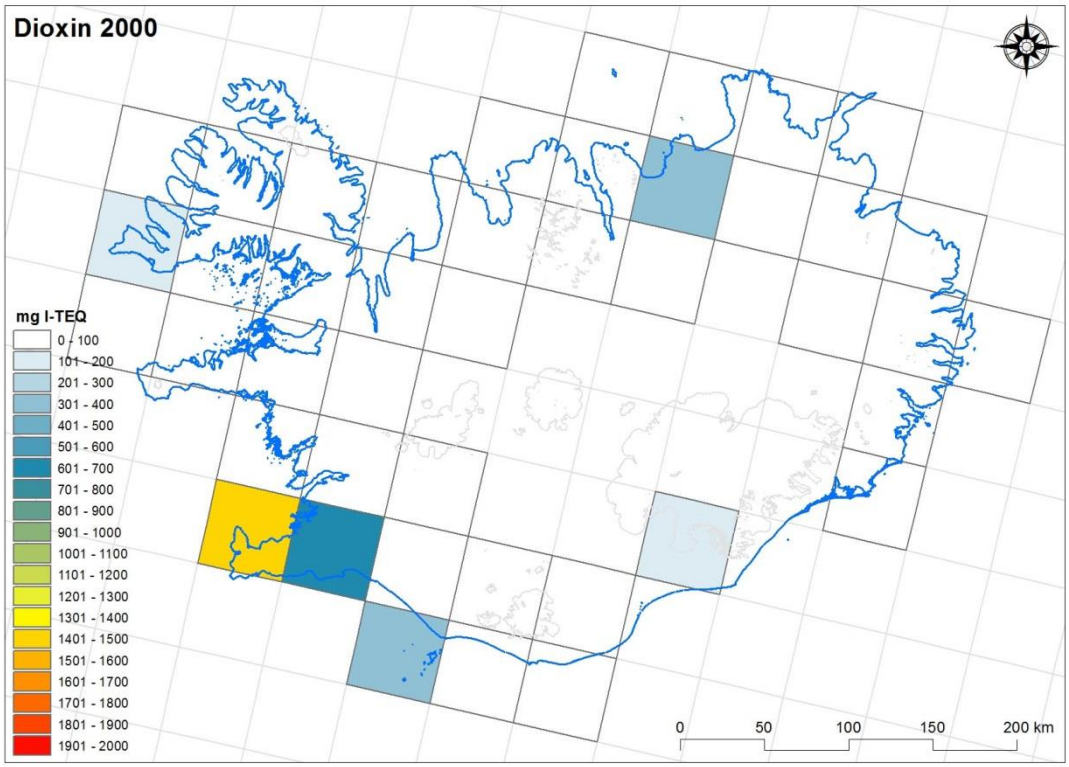

Figure 9.8. Emissions of dioxins within the EMEP-Grid in 2000.

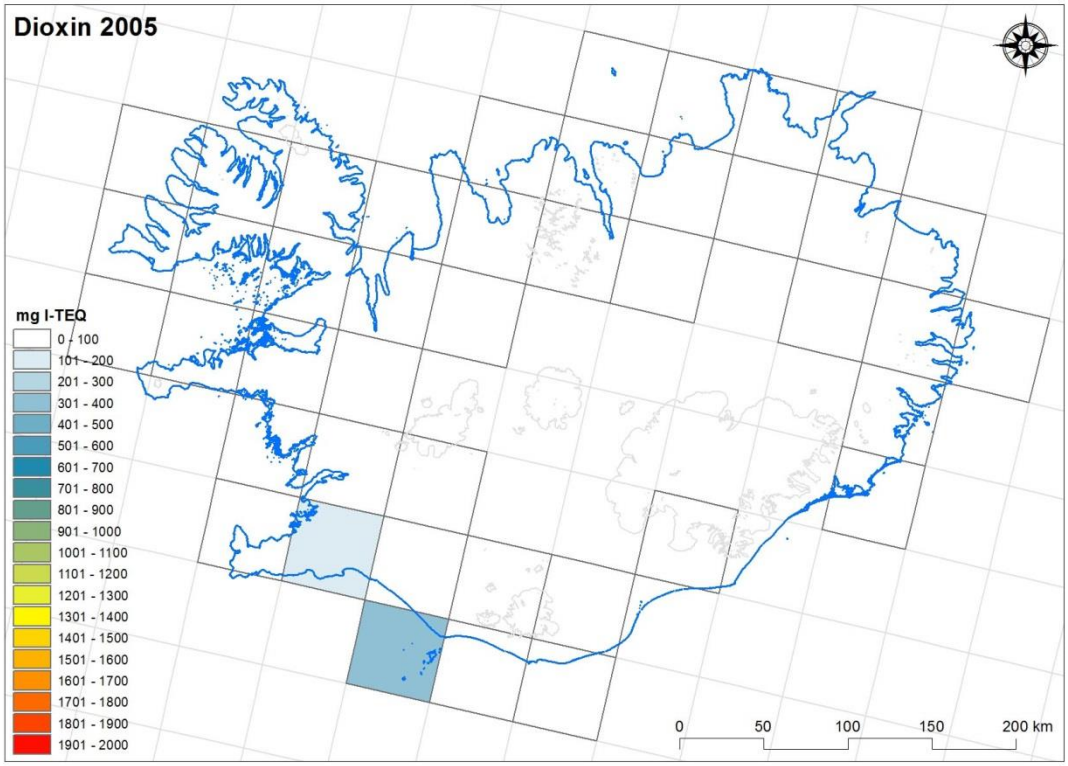

Figure 9.9. Emissions of dioxins within the EMEP-Grid in 2005.

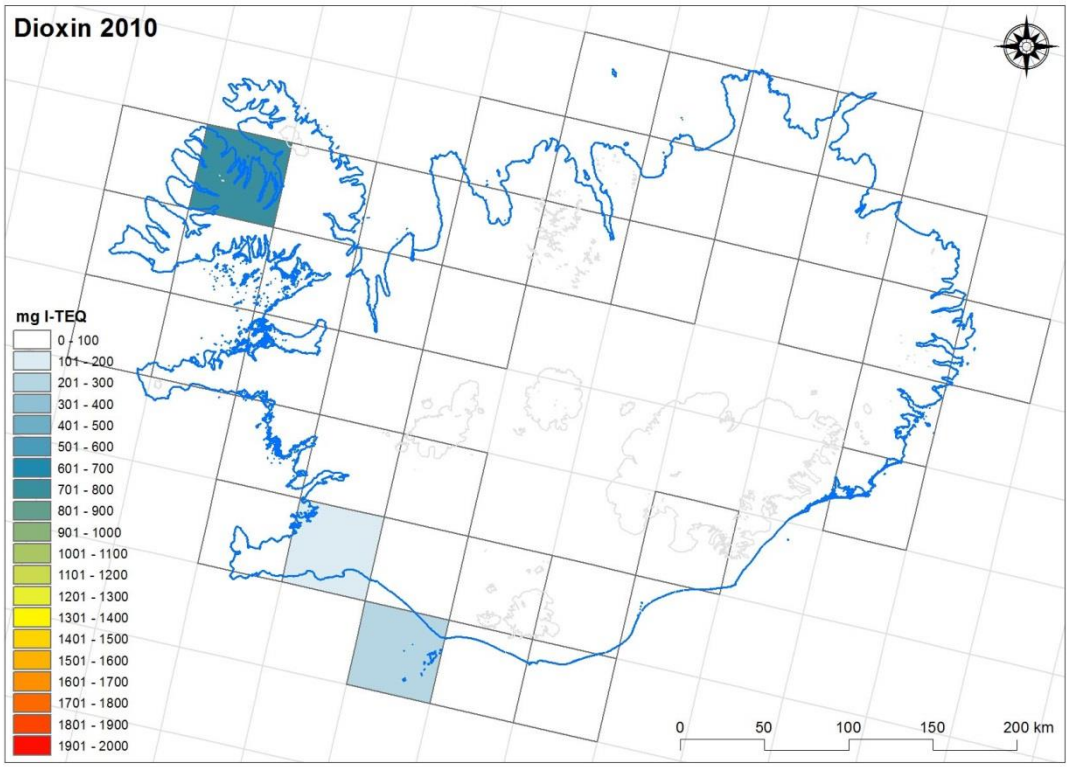

Figure 9.10. Emissions of dioxins within the EMEP-Grid in 2010.

For the distributed national totals, spatial patterns from the major sectors are recognisable. For PAH4 it can be seen how emissions in the areas with highest population density as well as the industrial sites become more over time. For dioxin the influence of closing down sites for open pit burning results in lower emissions over time. Further the malfunctioning of the incineration plant at Ísafjörður (north-west Iceland, Westfjords) results in higher emissions in 2010 than in the years before.

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ANNEX I EXPLANATION OF EA'S ADJUSTMENT OF DATA ON FUEL SALES BY SECTOR

Fuel sales (gas oil and residual fuel oil) by sectors 1A1a, 1A2 (stationary) and 1A4 (stationary) – as provided by the National Energy Authority

No.	Category	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
		Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes	Tonnes
Gas/Diesel Oil																	
10X40	house heating and swimming pools	8,535	10,511	7,559	9,797	10,034	7,625	6,349	5,756	3,665	4,428	4,240	2,417	2,420	1,546	1,626	1,637
10X5X	industry	1,129	1,998	2,500	5,803	8,093	8,920	9,443	10,233	22,762	24,995	15,196	15,455	12,819	7,217	9,100	6,663
10X60	energy industries	1,091	1,252	631	564	820	1,065	897	1,112	631	112	21	1,349	1,109	1,436	760	1,012
10X90	other	458	69	12	909	1,063	1,386	1,323	756	1,832	8,124	8,928	8,296	2,033	1,336	1,499	2,728
Residual Fuel Oil																	
10840	house heating and swmimming pools	3,079	1,749	701	661	236	122	162	203	118	37	195	76	86	63	78	0
1085X	industry	56,172	71,280	80,461	64,958	64,303	46,146	55,782	64,026	48,547	28,230	25,005	23,635	22,708	19,562	17,646	14,917
10860	energy industries	0	18	58	816	230	-53	0	23	0	0	0	5	4,498	0	0	0
10890	other	52	53	-4	669	319	67	4,978	6,465	319	6,139	0	0	45	913	0	1,629

ADJUSTMENTS

For gas oil:

First fuel consumption needed for the known electricity production with fuels is calculated(**1A1a** – electricity production), assuming 34% efficiency, The values calculated are compared with the fuel sales for the category 10X60 Energy industries.

- In years where there is less fuel sale to energy industries as would be needed for the electricity production, the fuel needed is taken from the categorie 10X90 Other and when that is not sufficient from the category 10X40 House heating and swimming pools.
- In years where there is surplus the extra fuel is added to the category 10X40 House heating and swimming pools.

NEA has estimated the fuel use by swimming pools (**1A4a**), These values are subtracted from the adjusted 10X40 category, The rest of the category is then **1A4b** – Residential.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Swimming pools	1,600	1,600	1,600	1,600	1,600	1,600	1,400	1,400	1,200	1,100	1,000	300	300	300	300	300

For years when there is still fuel in the category 10X90 Other, this is added to the 10X5X Industry, This is the fuel use in **1A2** – Industry.

For Residual Fuel Oil:

The sectors 10840 and 10860 are added together. This is the fuel use by **1A1a** - public heat plants, In year 1997 four tonnes are subtracted from this category as the category 10890 has minus four tonnes, leaving category 10890 with 0 in 1997.

The categories 1085X Industry and 10890 Other are added together, This is the fuel use in 1A2 – industry.